Title: Physics Beyond the Horizon

Date: Jan 25, 2008 03:00 PM

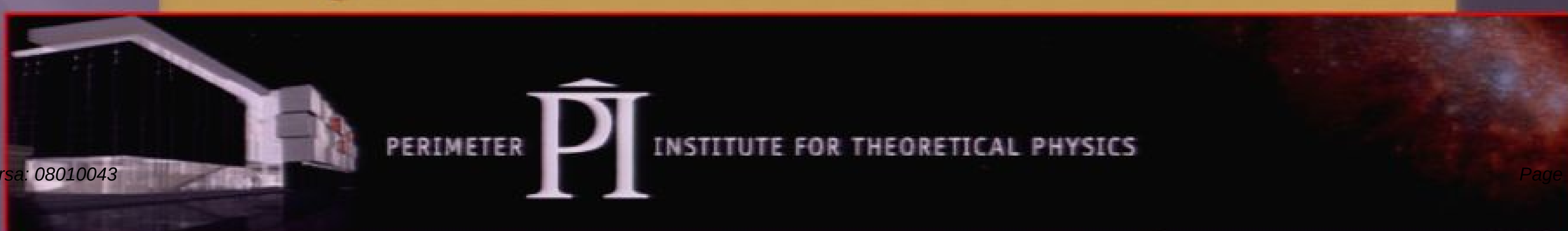
URL: http://pirsa.org/08010043

Abstract: The history of human knowledge is often highlighted by our efforts to explore beyond our apparent horizon. In this talk, I will describe how this challenge has now evolved into our quest to understand the physics at/beyond the cosmological horizon, some twenty orders of magnitude above ColumbusÂ’s original goal. I also argue why inflationary paradigm predicts the existence of non-trivial physics beyond the cosmological horizon, and how we can use the Integrated Sachs-Wolfe effect in the Cosmic Microwave Background to probe this physics, including the nature of gravity and primordial non-gaussianity on the horizon scale.

PHYSICS

BEYOND THE HORIZON

Niayesh Afshordi

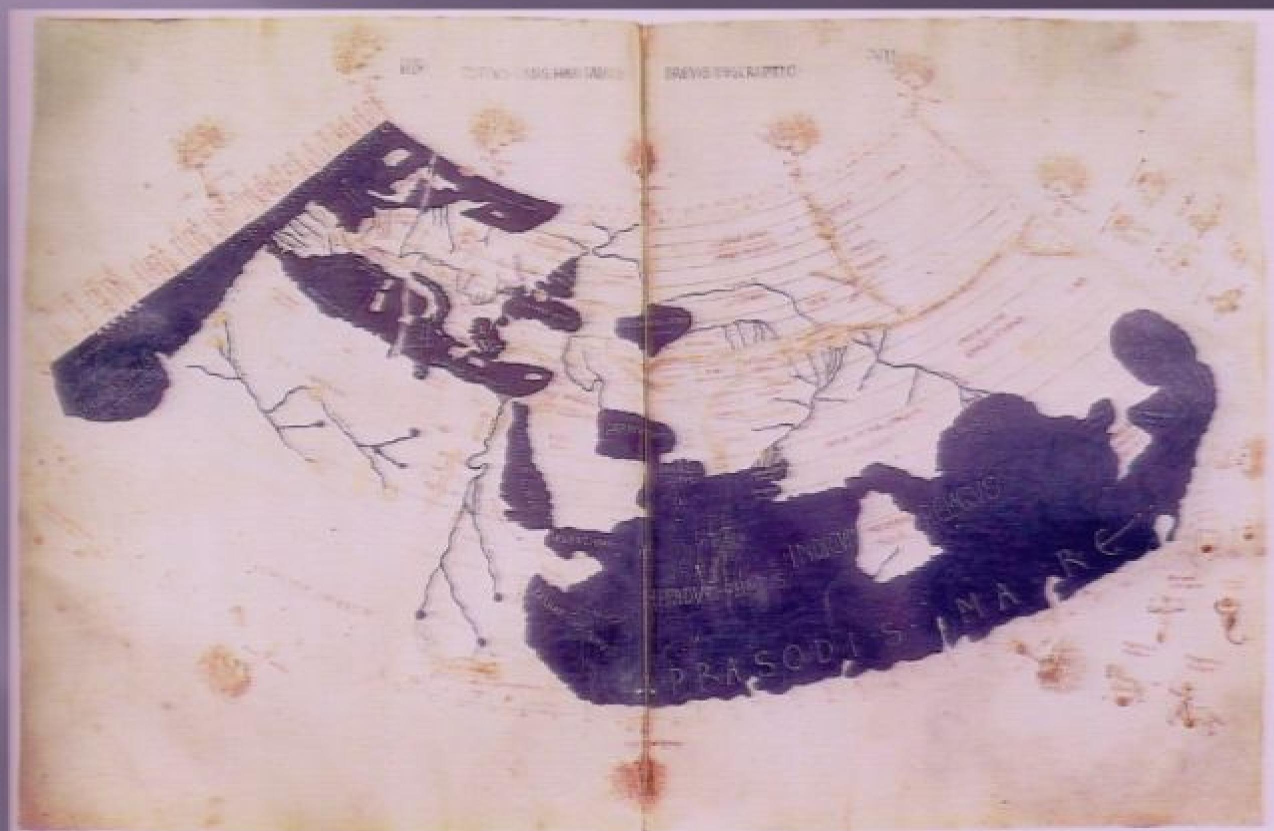


Perimeter Institute Observatory

PI

where Stars meet Strings

Cosmography vs Cartography



Ptolemy's 150 AD World Map, 10^9 cm

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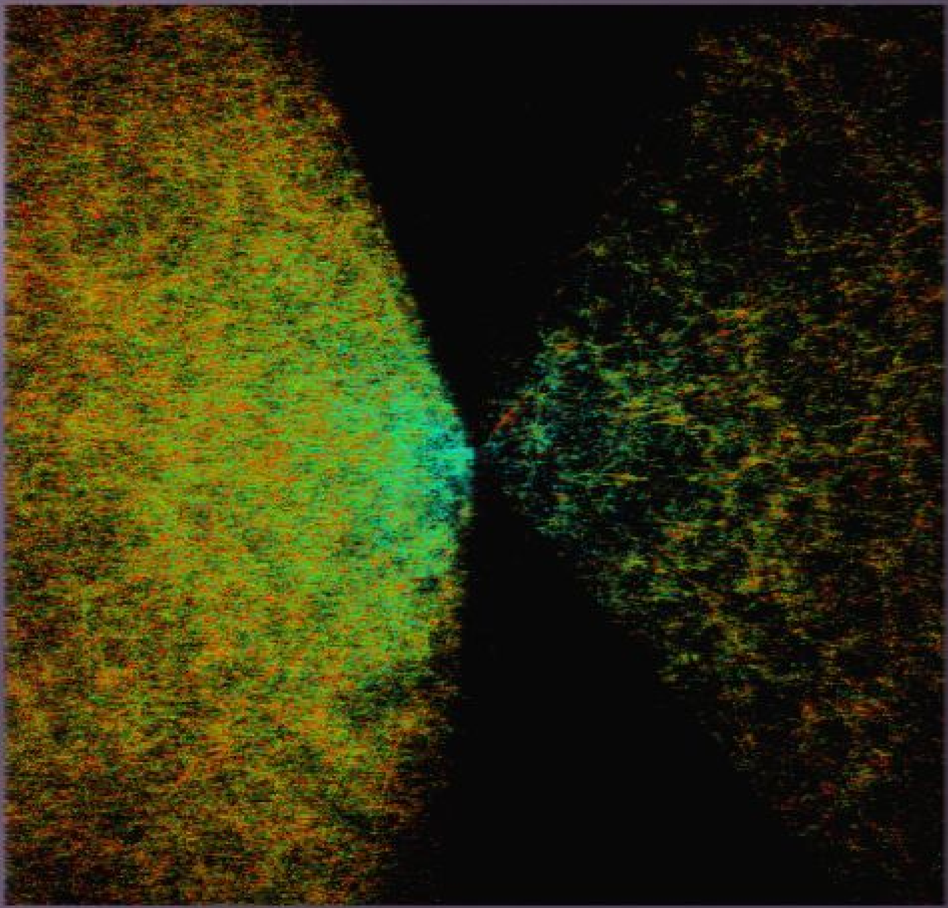

Sloan Digital Sky Survey: 1 Gpc ~ 10^{28} cm (due to Mike Blanton)

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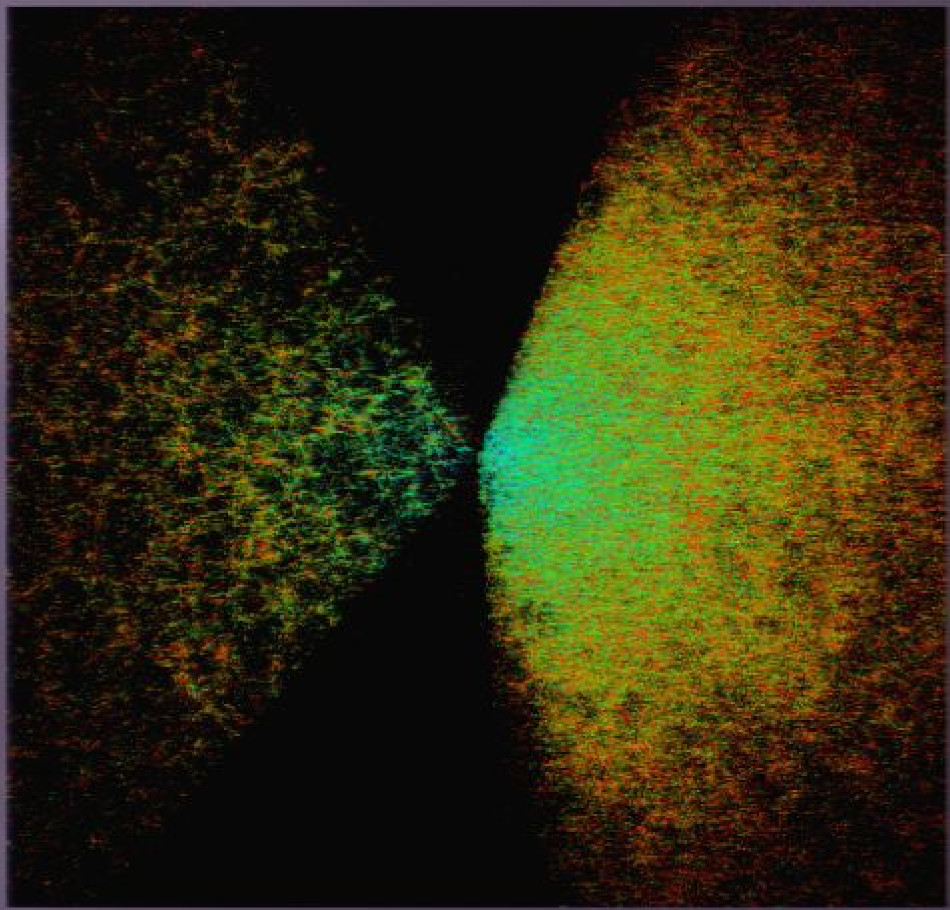

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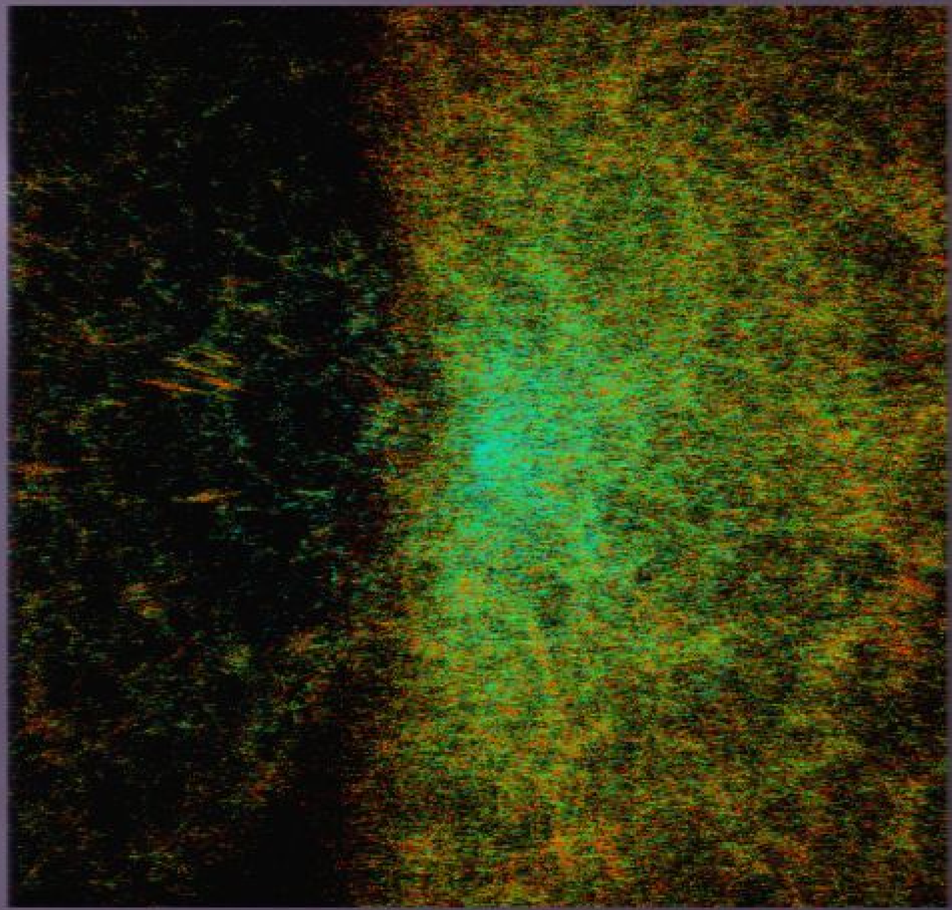

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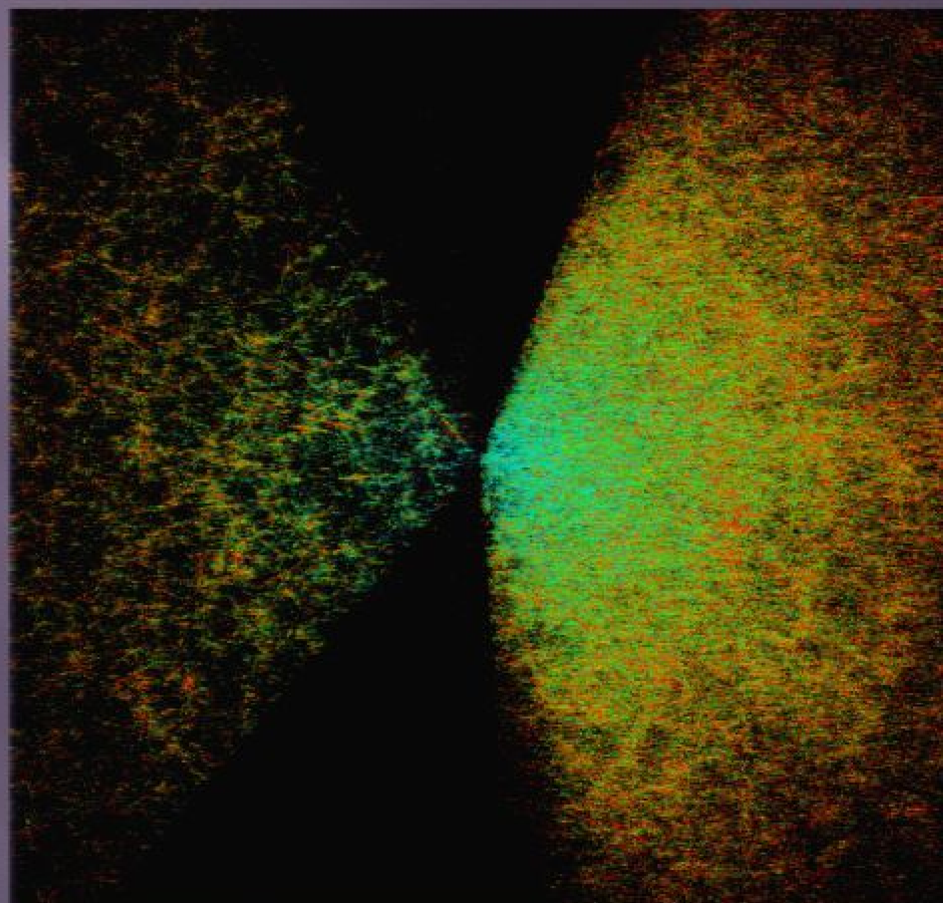

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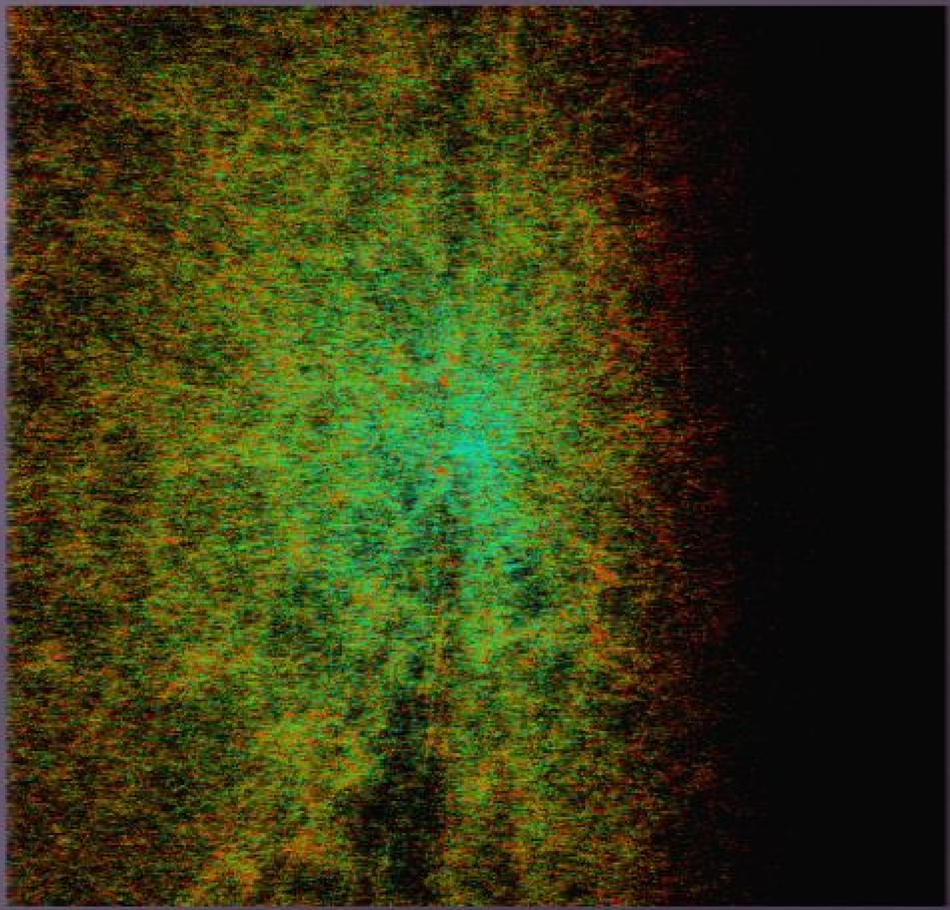

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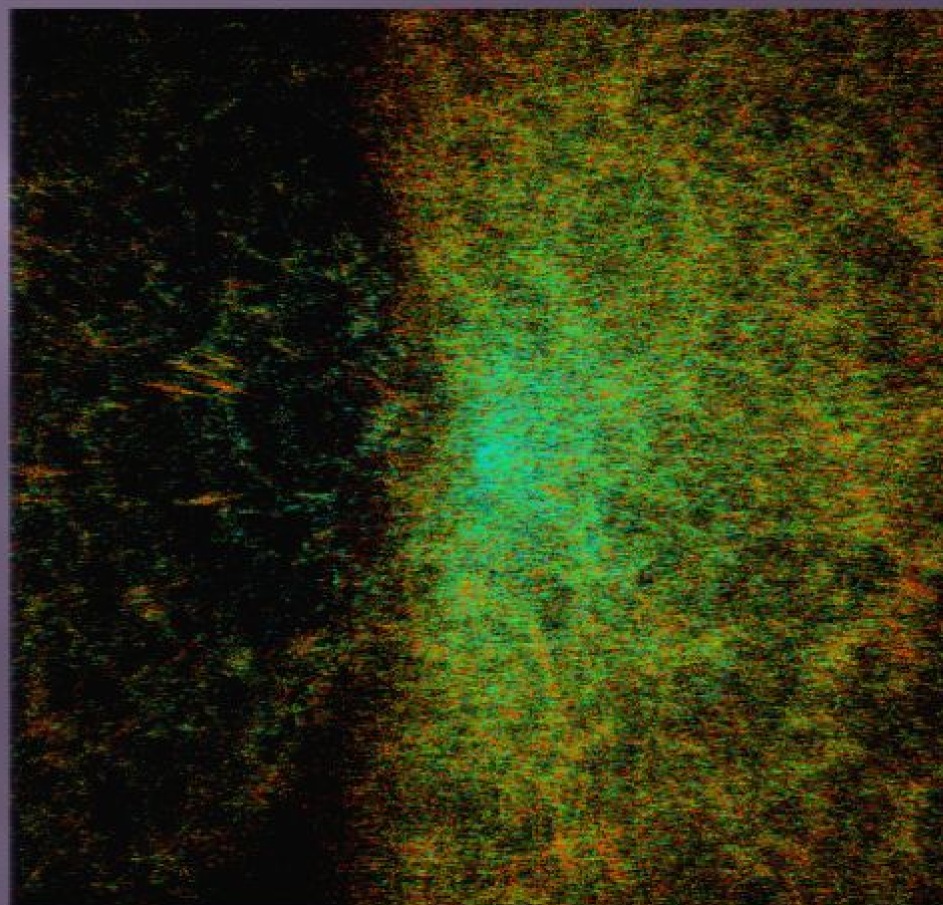

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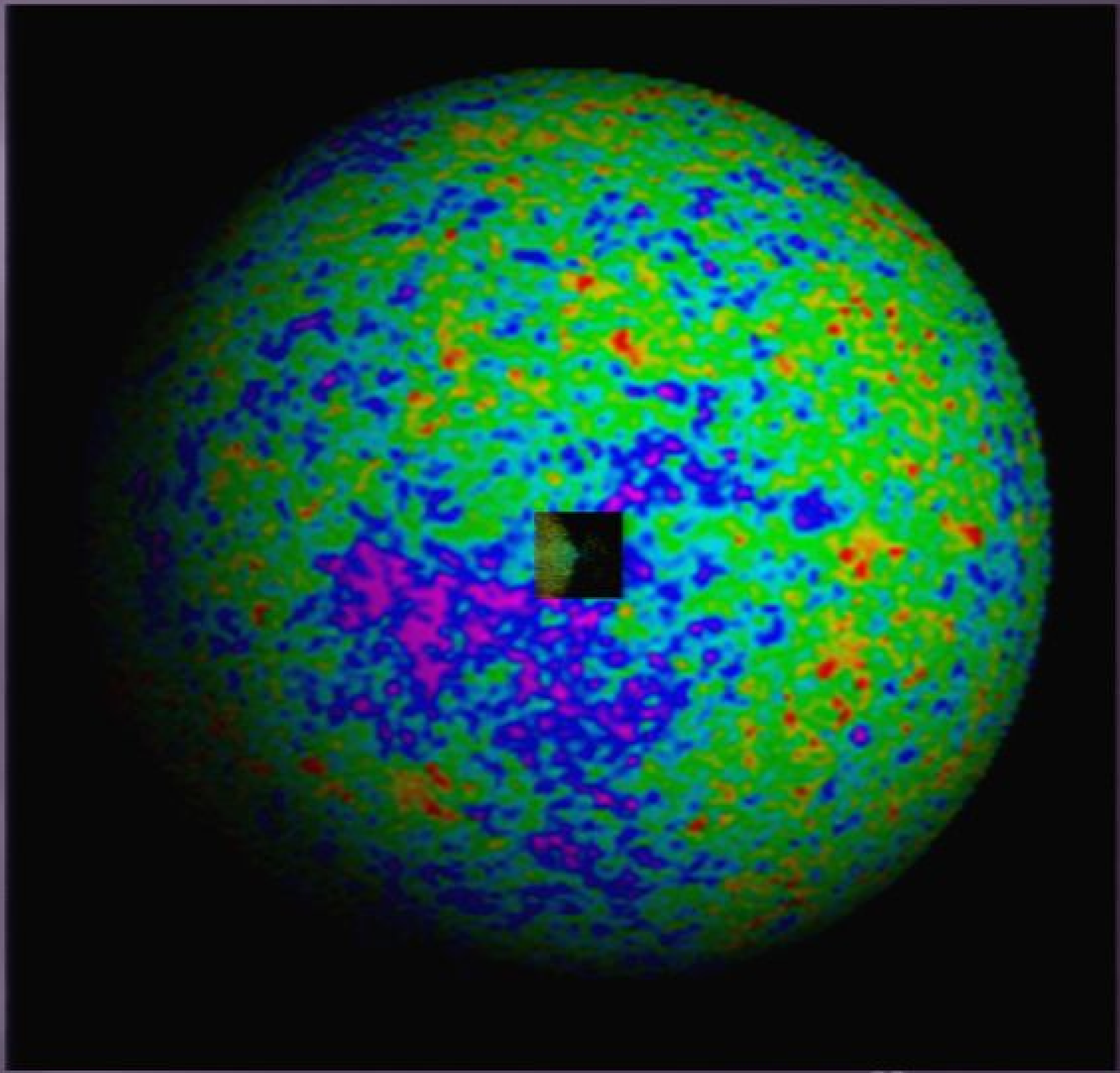

Wilkinson Microwave Anisotropy Probe: 10 Gpc ~ 10^{29} cm (due to Max Tegmark)

Our Horizon through time

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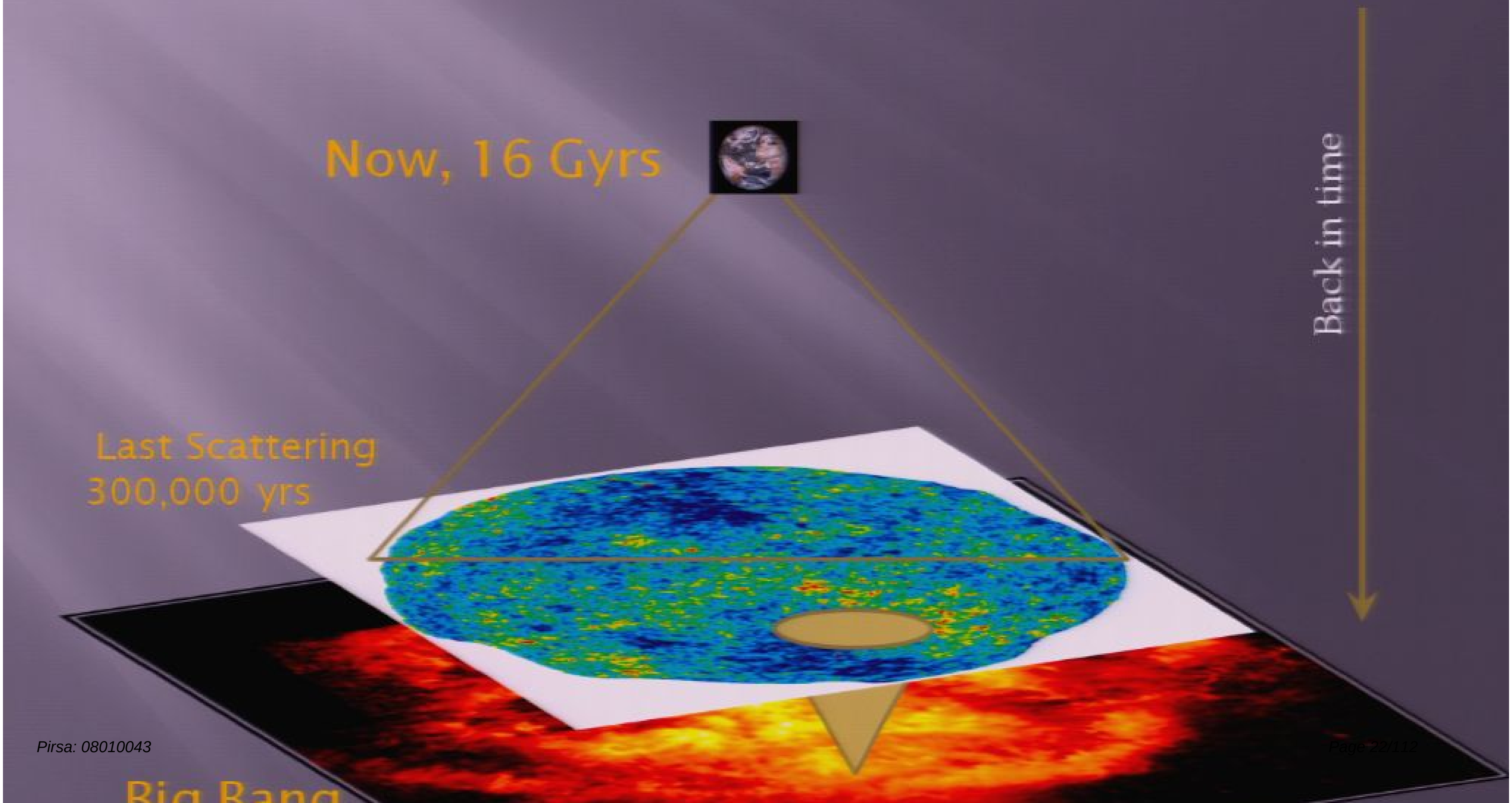
Horizon Problem

- At last scattering, causal horizon is much smaller than horizon today.



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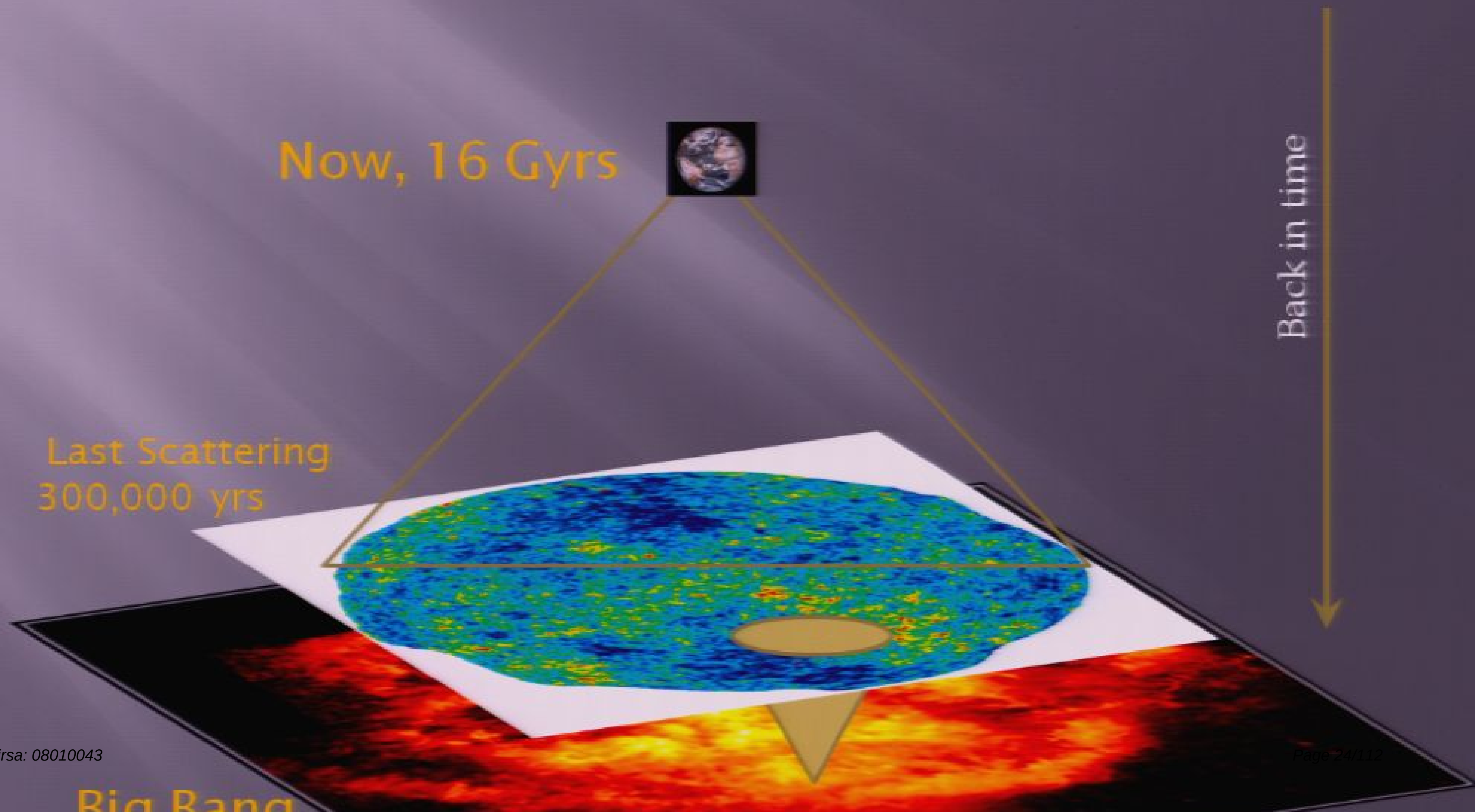

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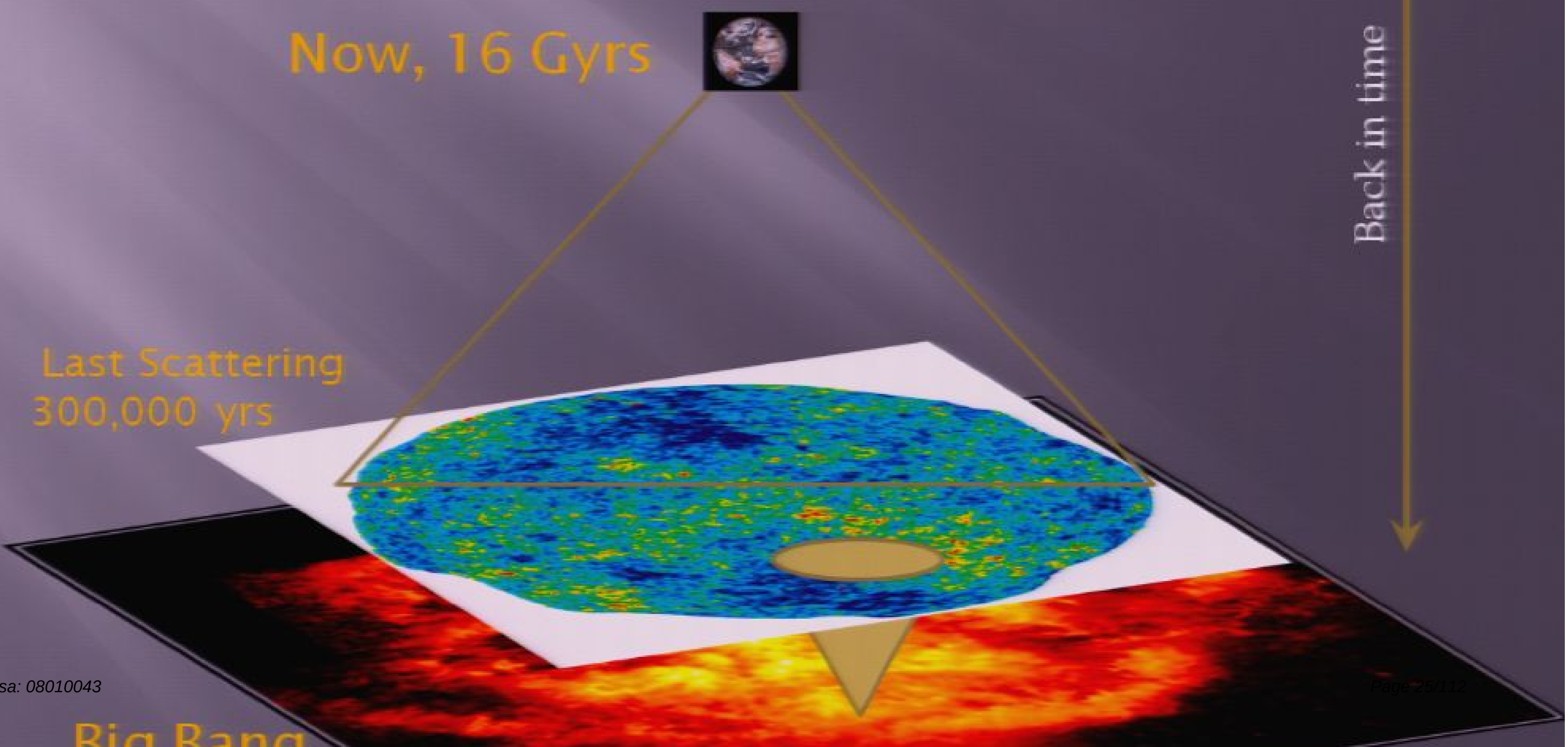

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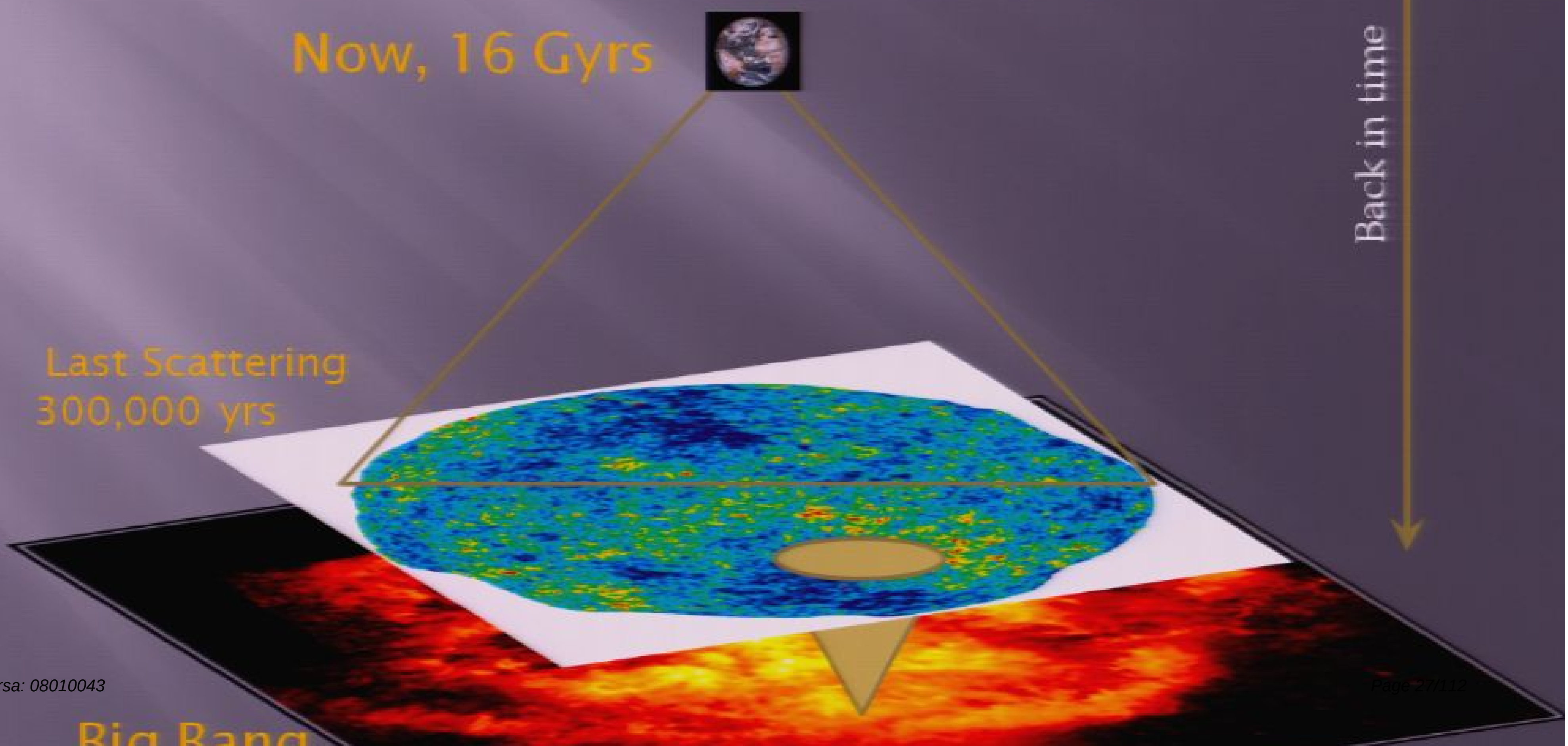

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- Other (model-dependent) features:
  - Non-gaussianity (secondary field, non-minimal kinetic term)
  - Gravitational waves (high energy scale inflation)

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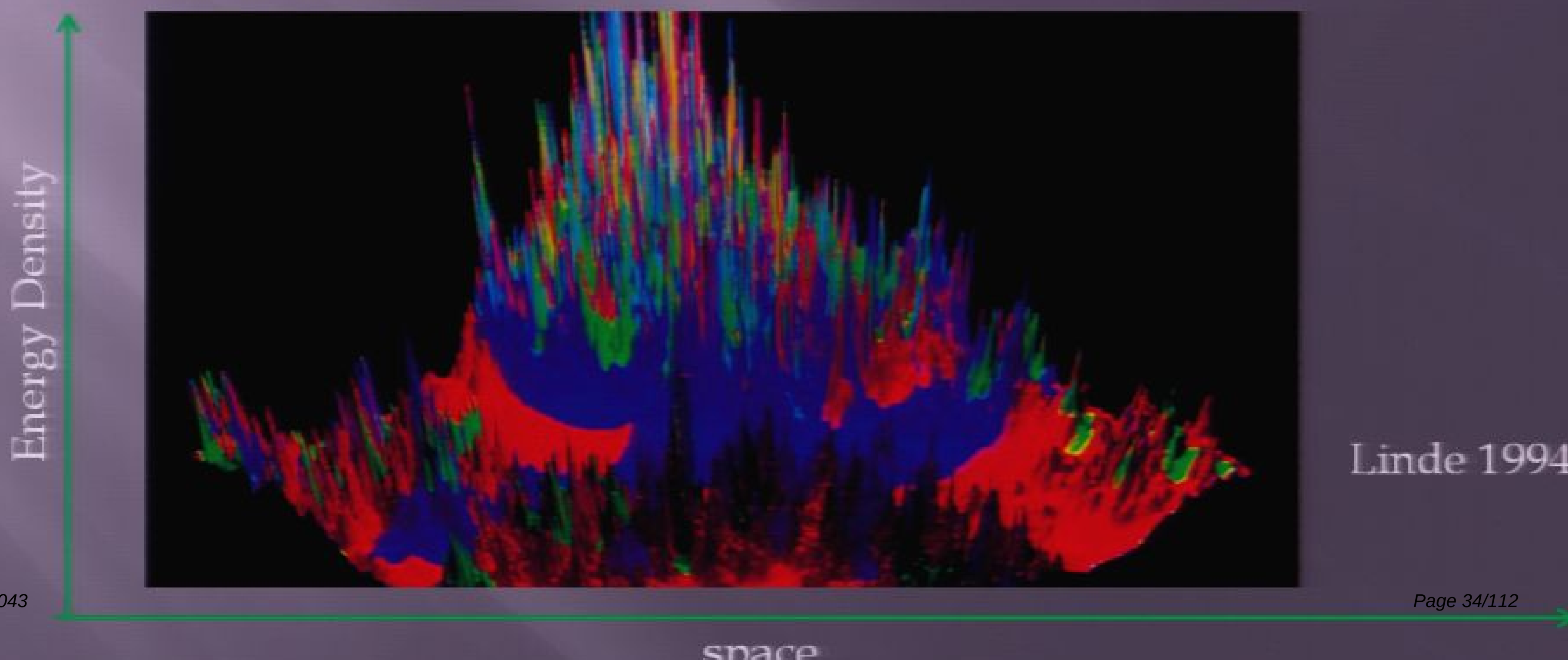

Linde 1994

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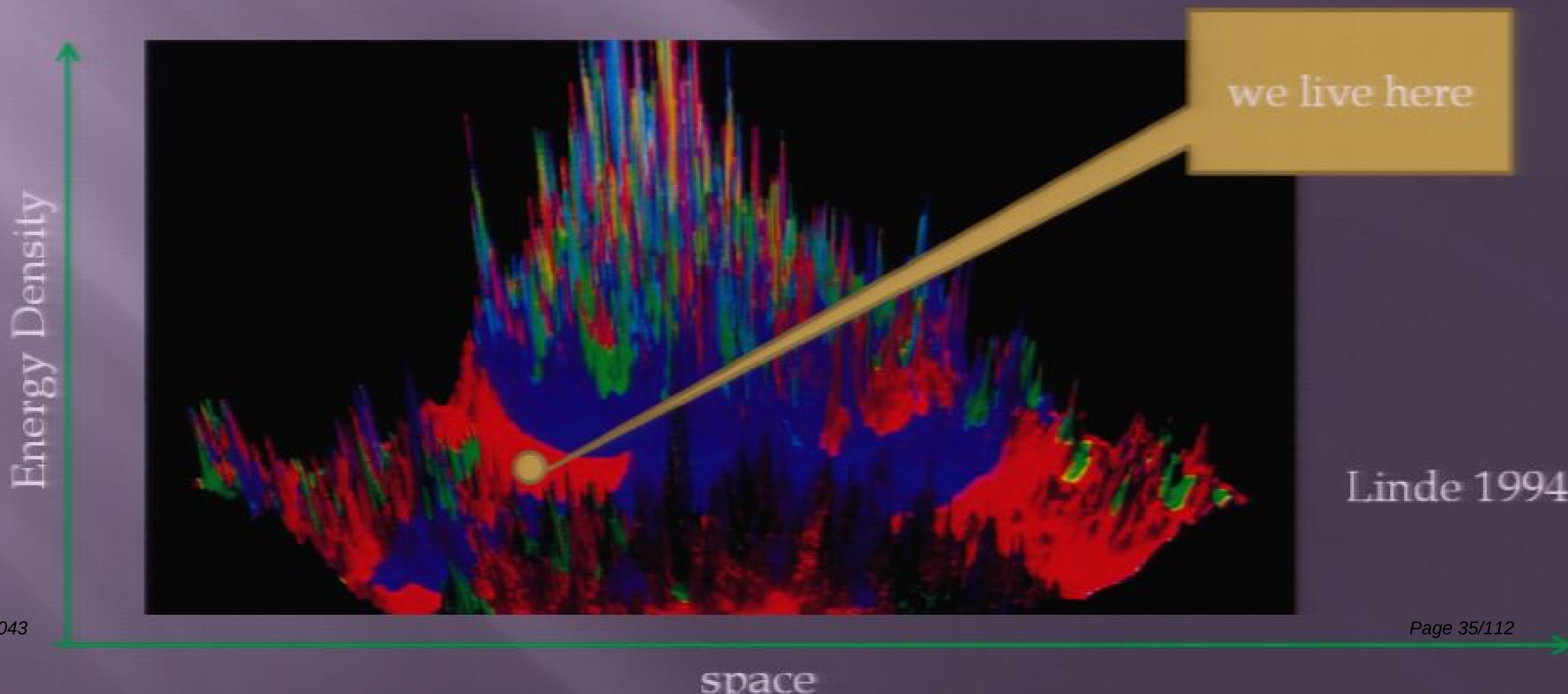

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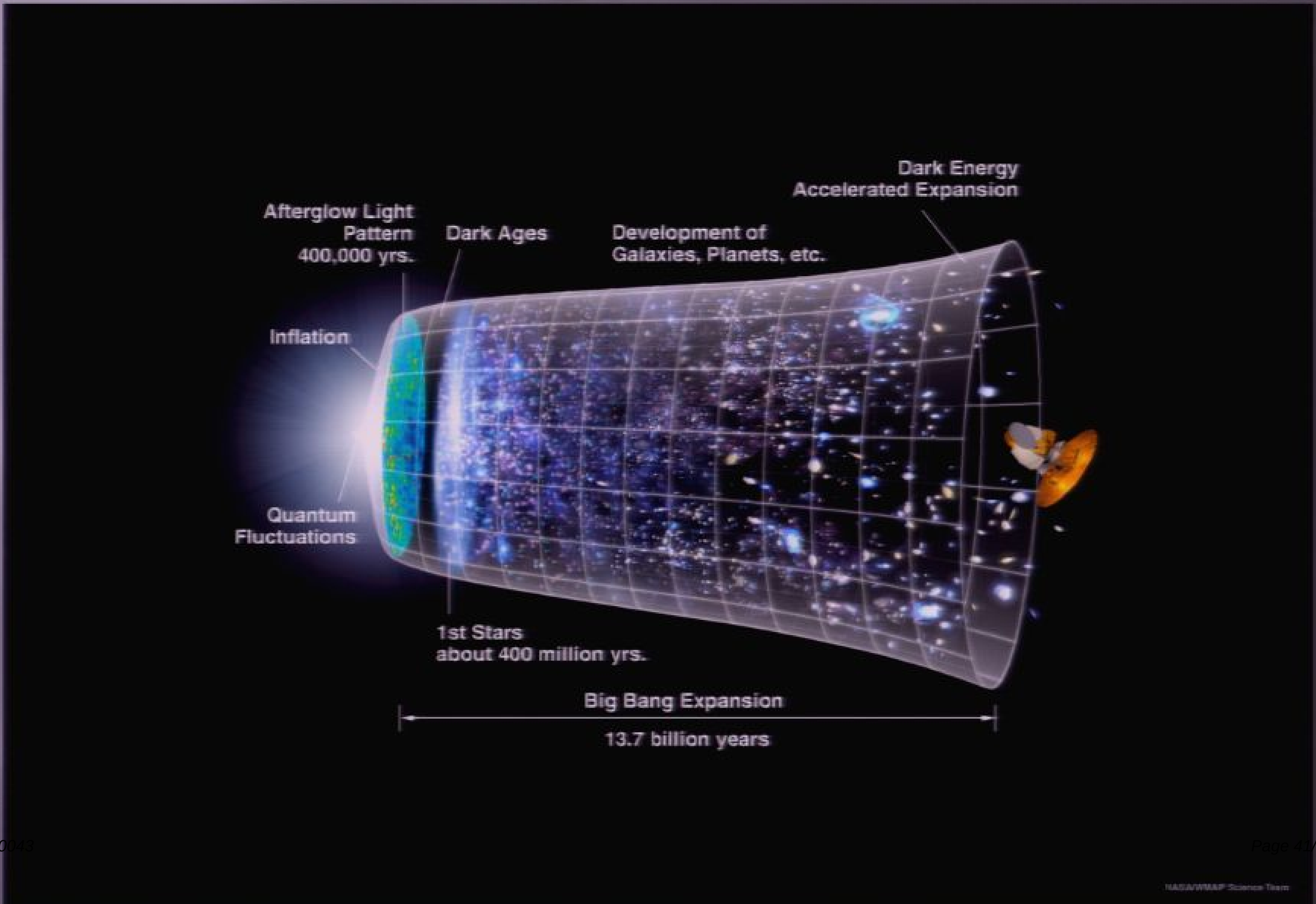
Physics beyond the Horizon:

- Cosmic acceleration and the ISW effect
- Gravity on Horizon scale
- Statistics on Horizon scale

Cosmic Timeline: Dark Energy Domination



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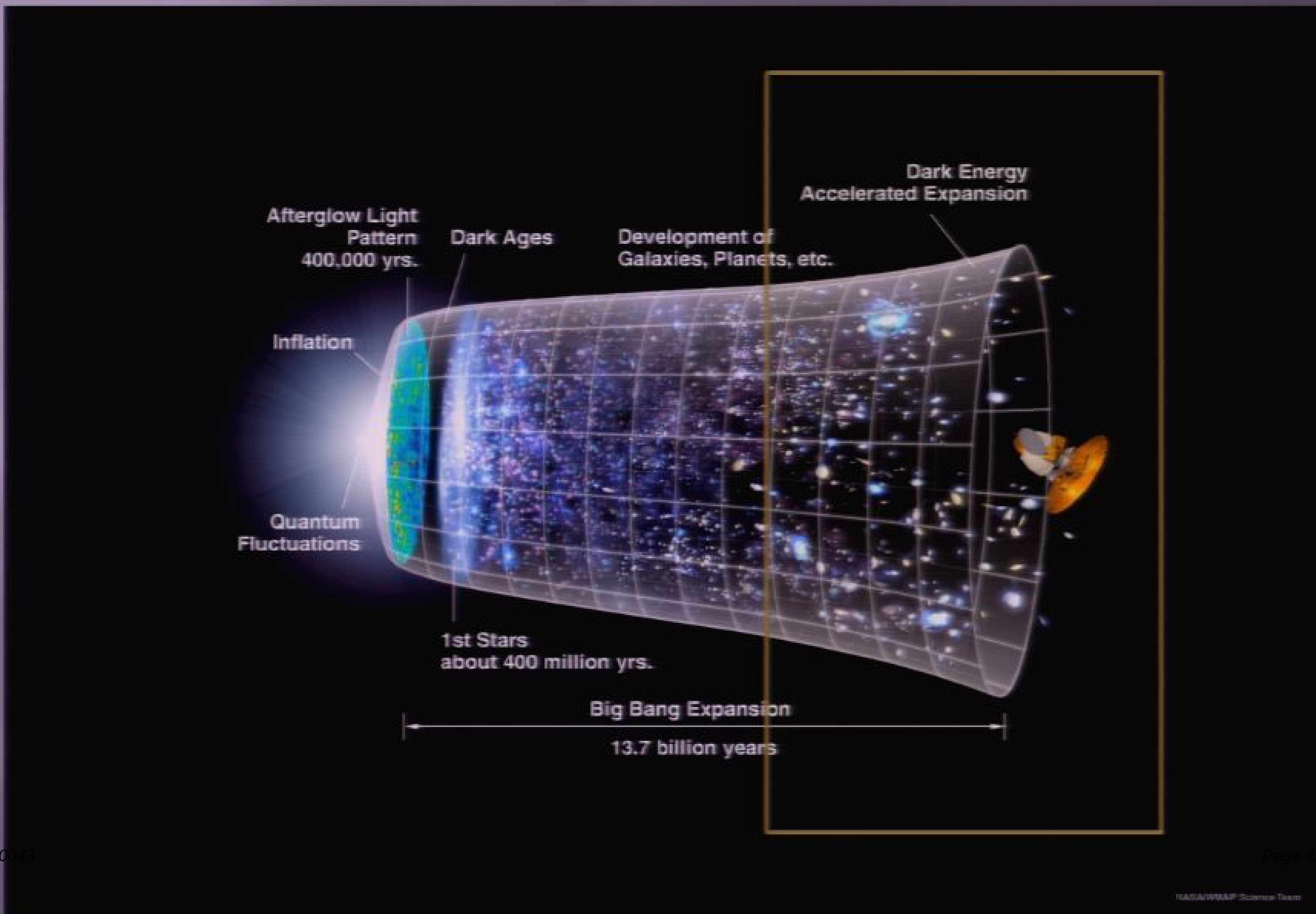
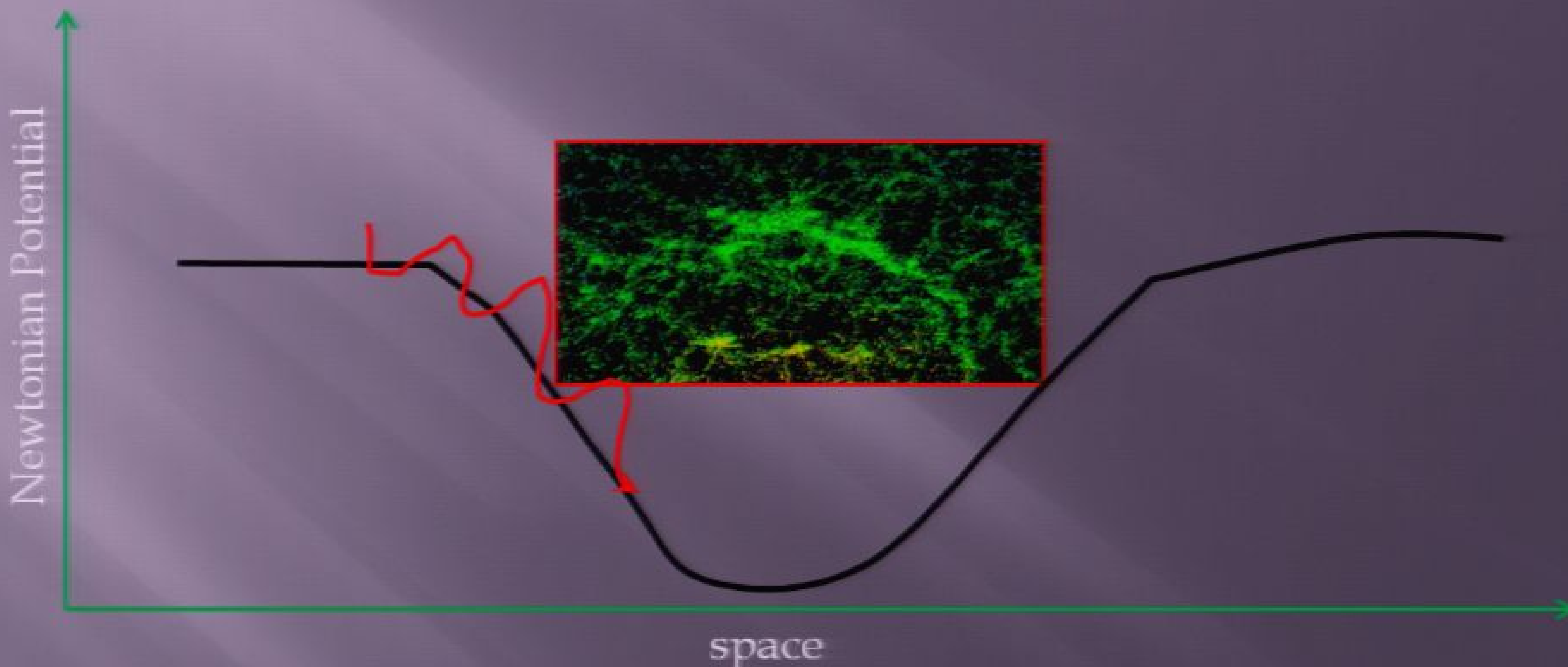


Integrated Sachs-Wolfe (ISW) effect



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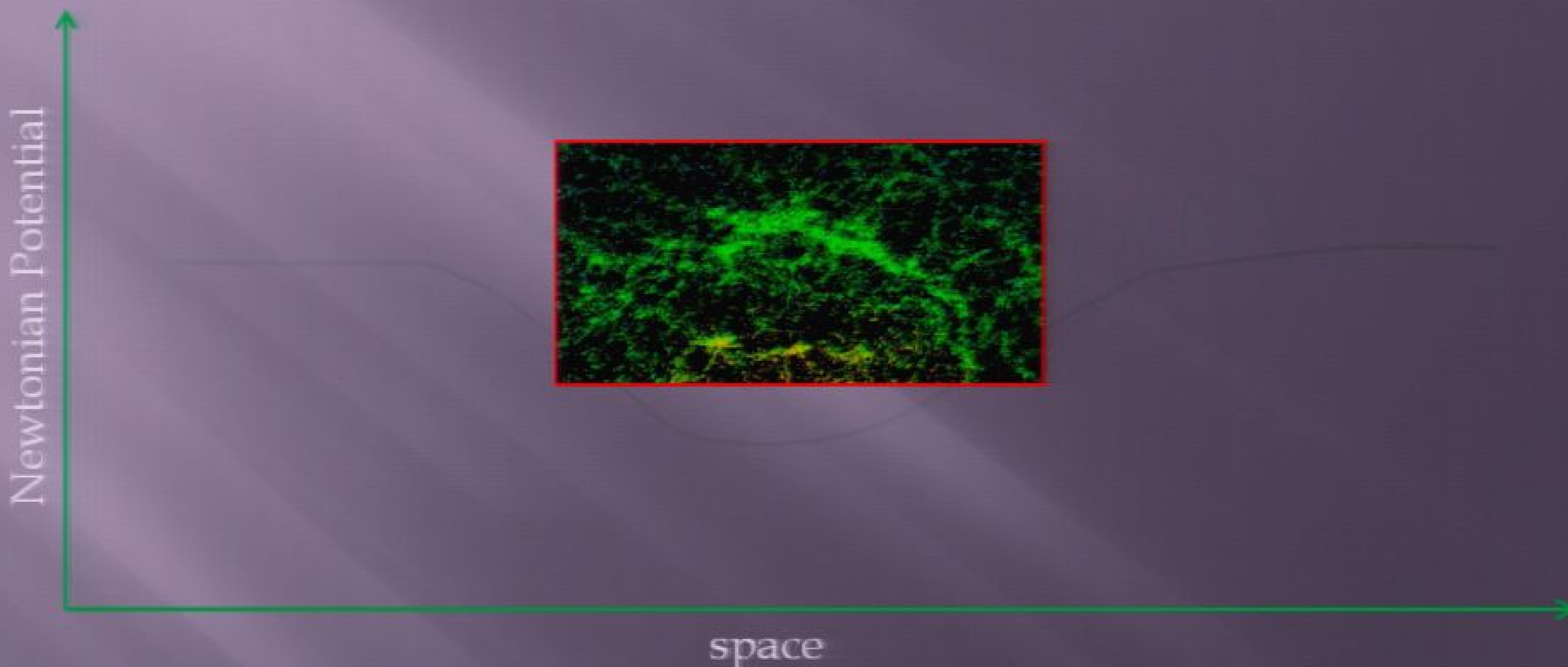

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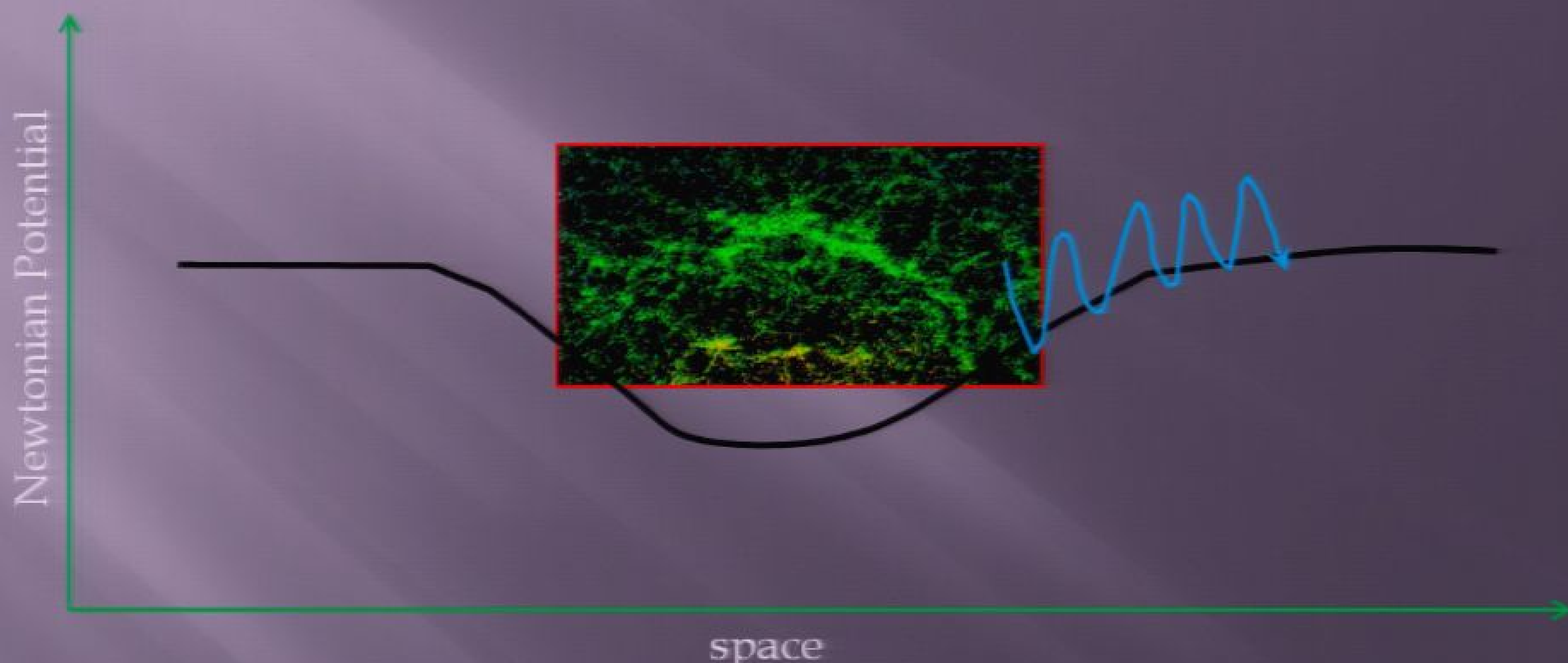

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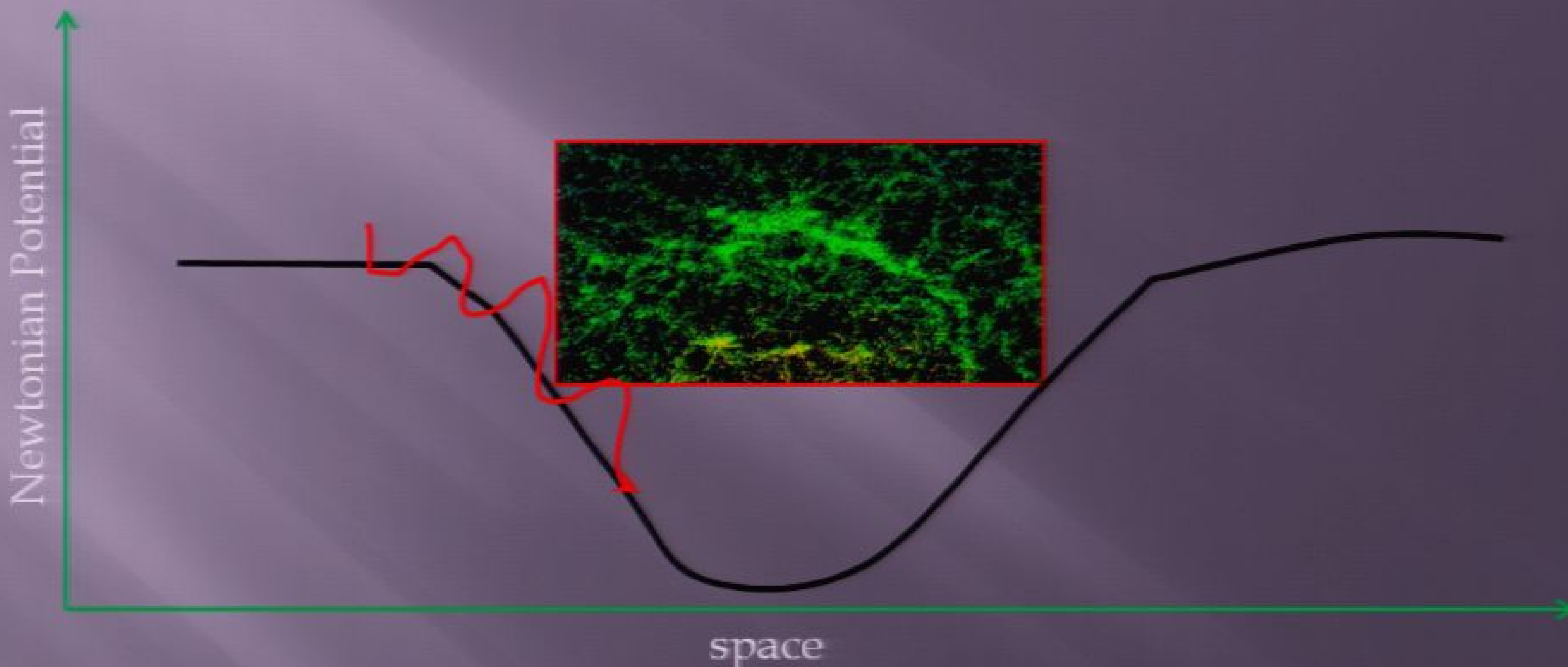

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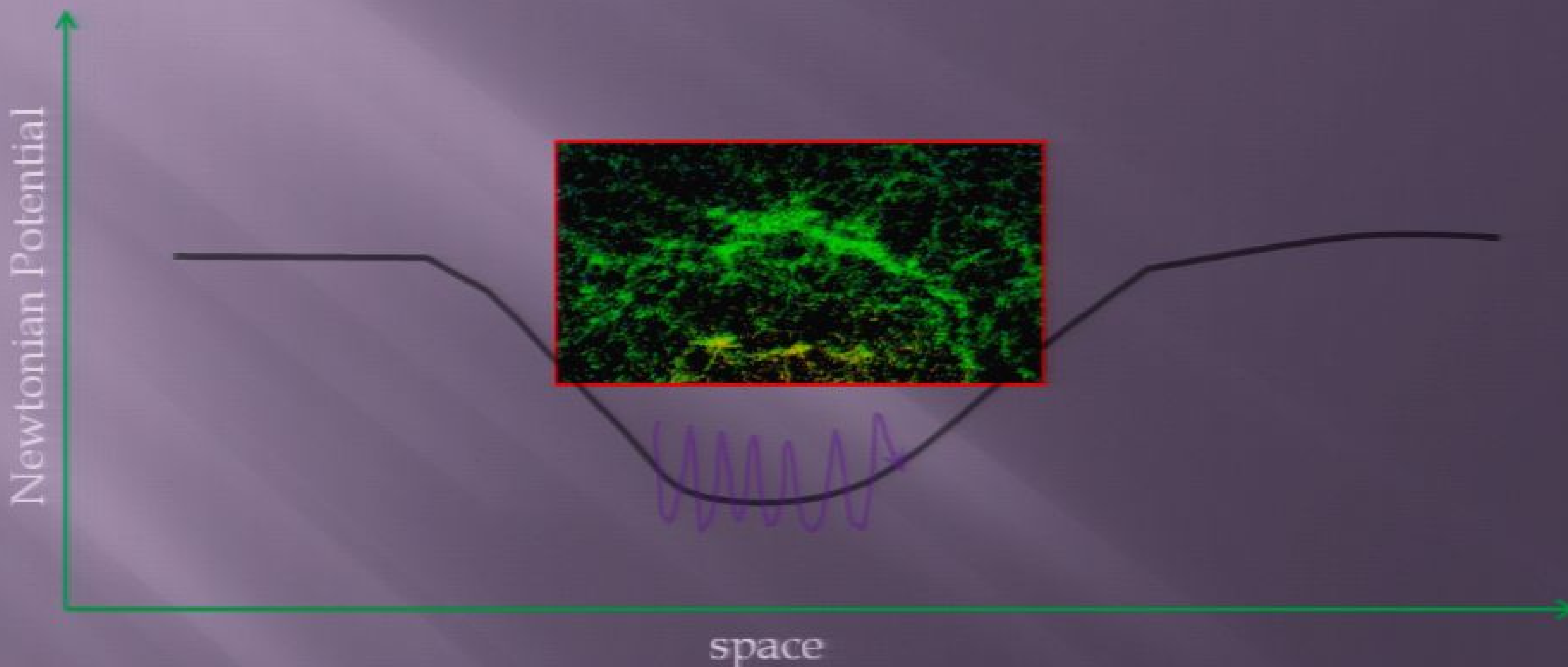

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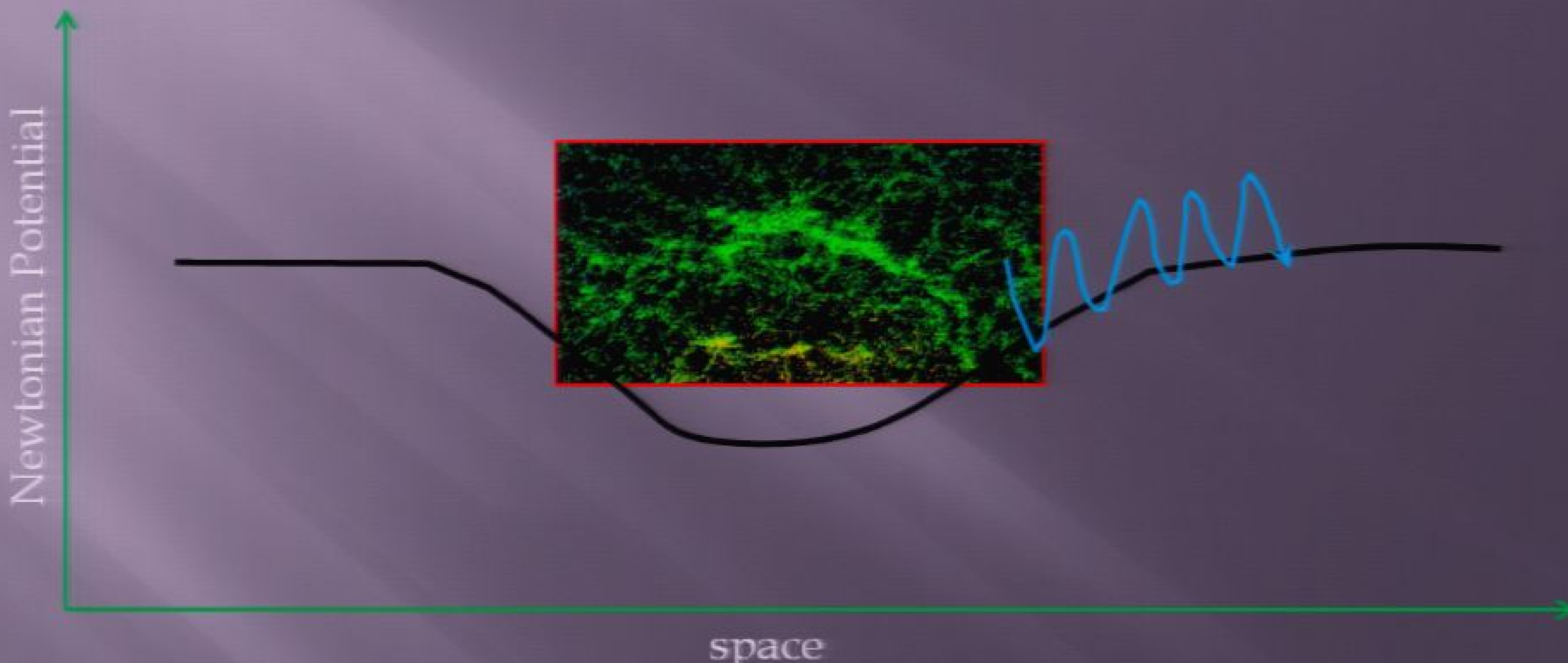

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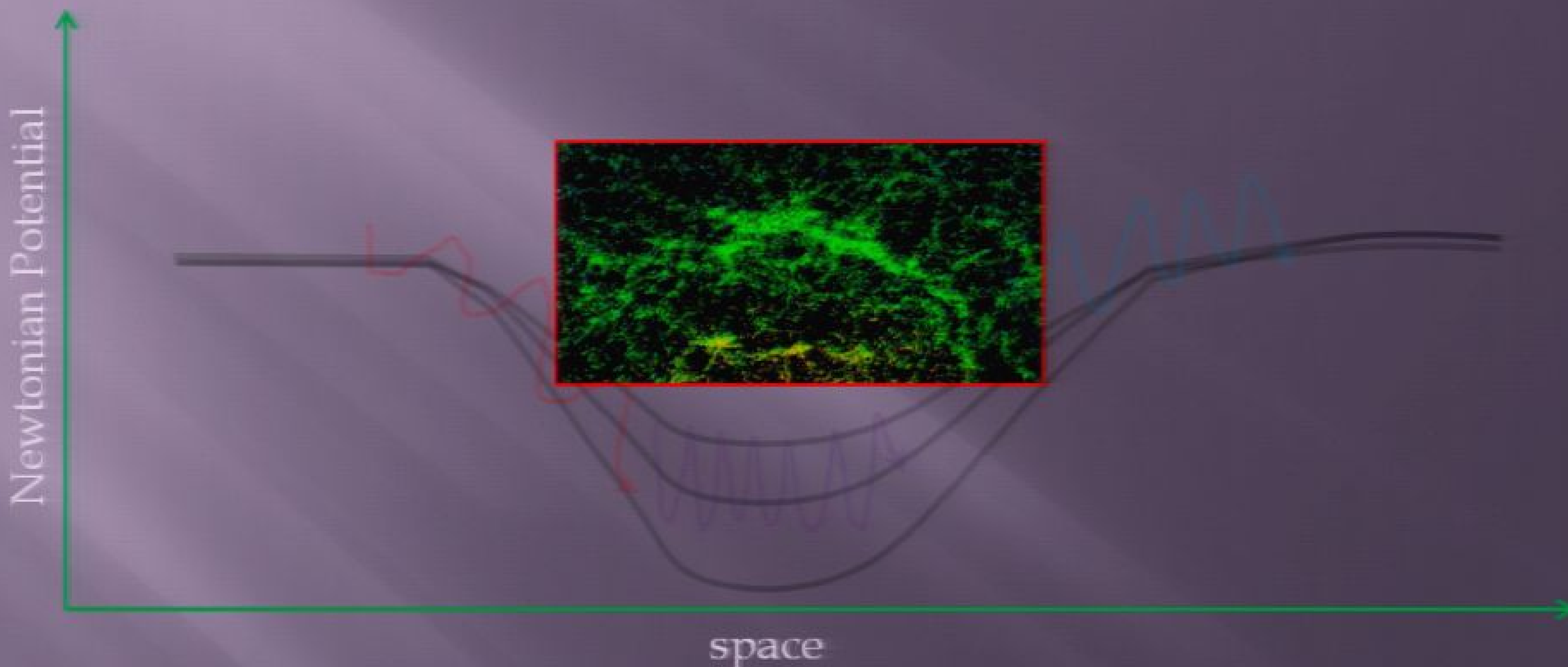

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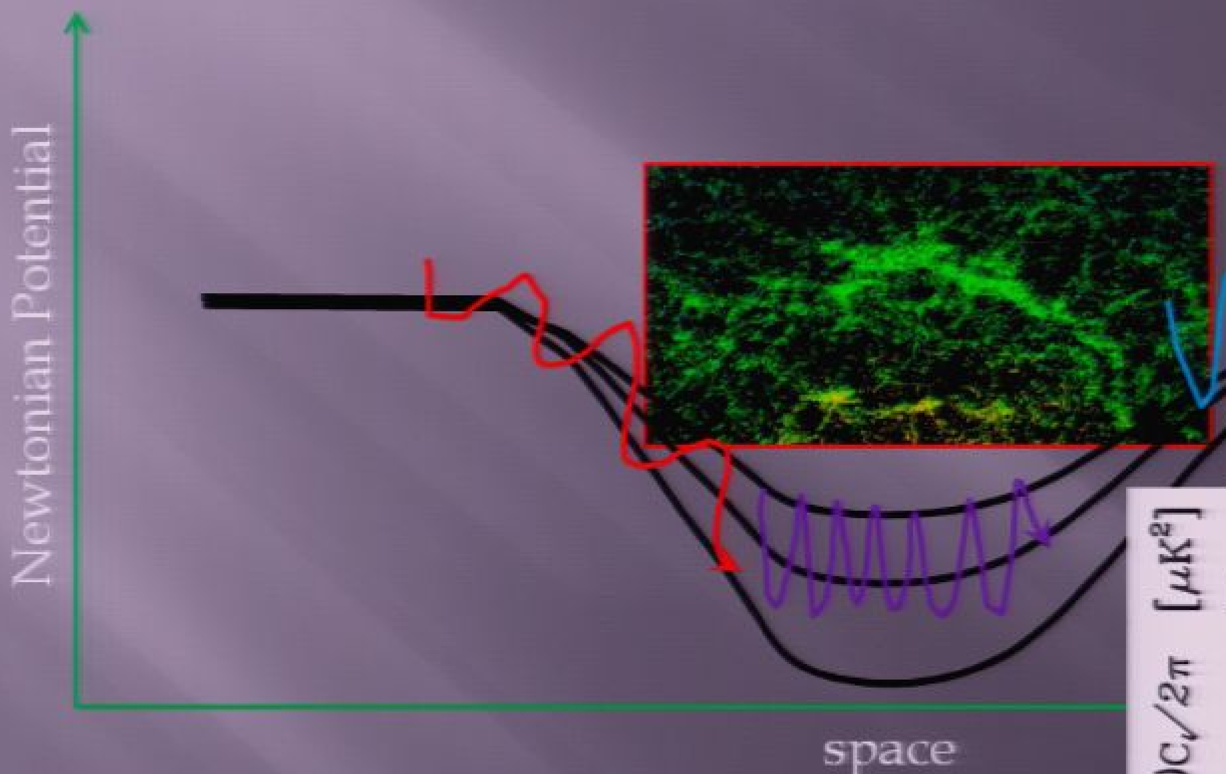

Spergel, et al. 06

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ISW in Cross-Correlation

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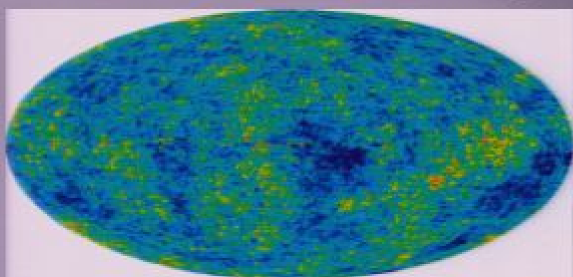

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Galaxies

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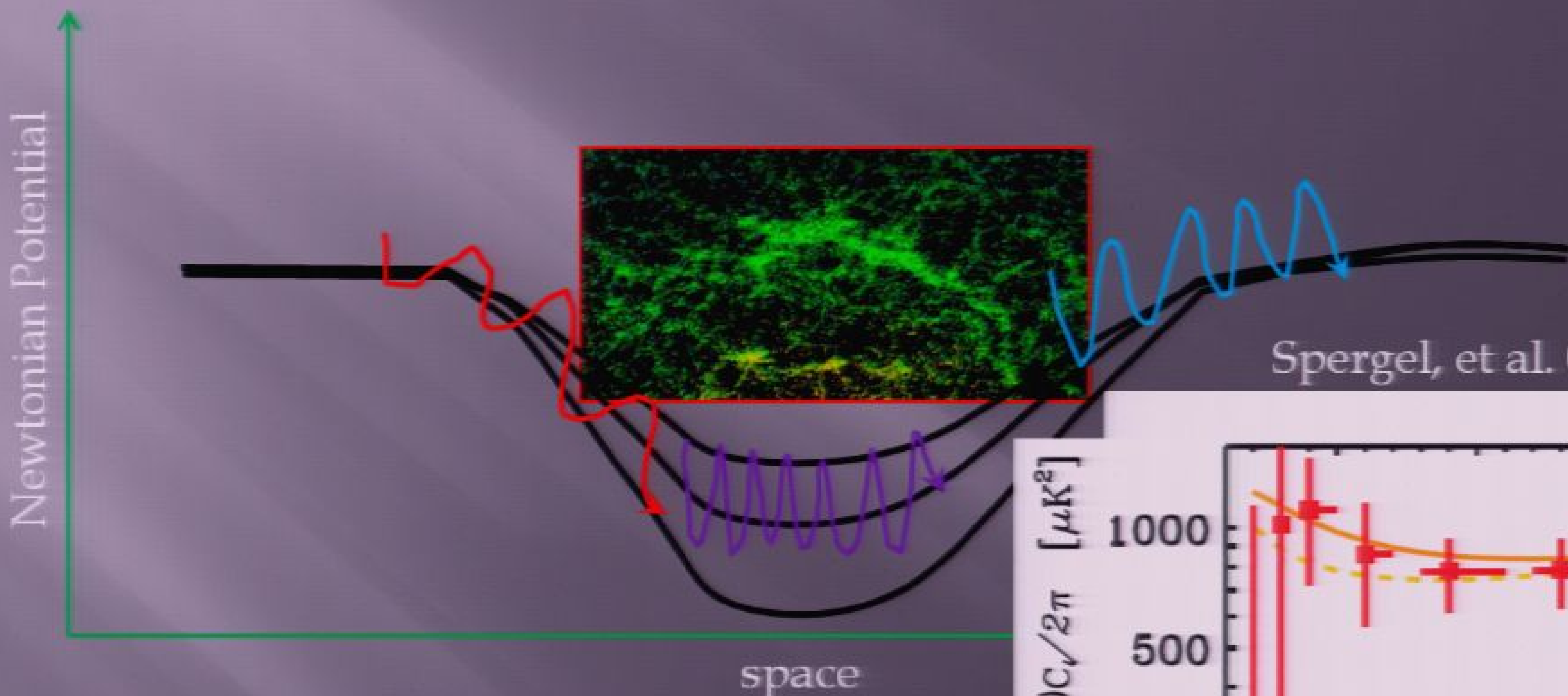

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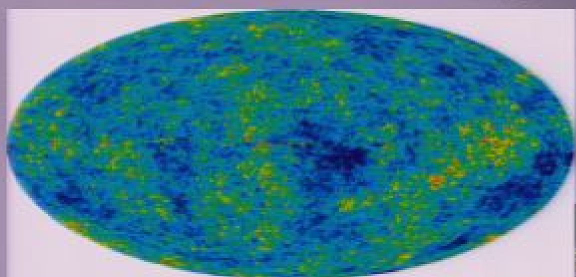

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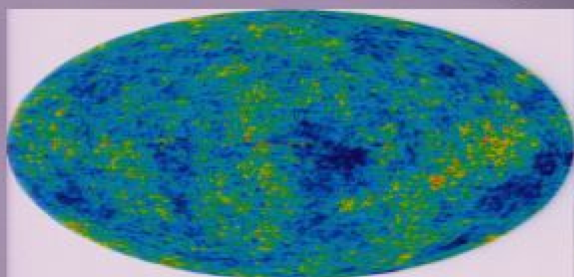

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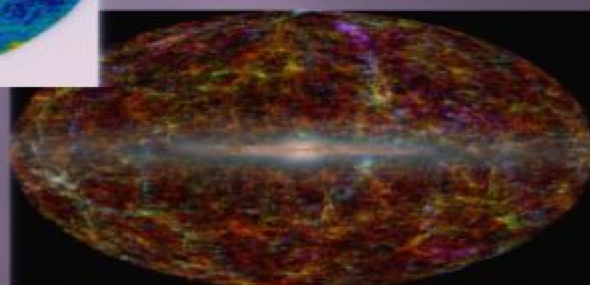

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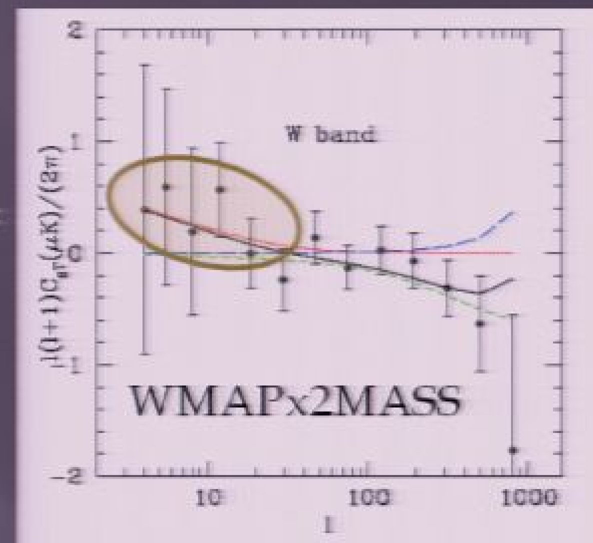

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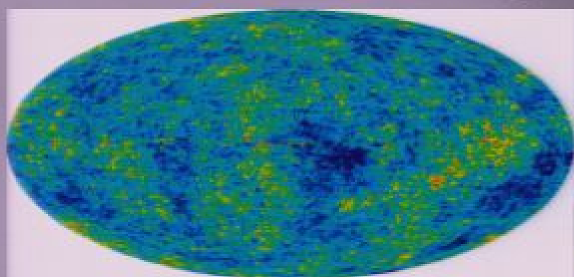

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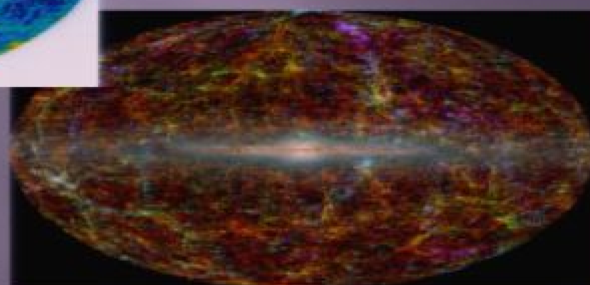

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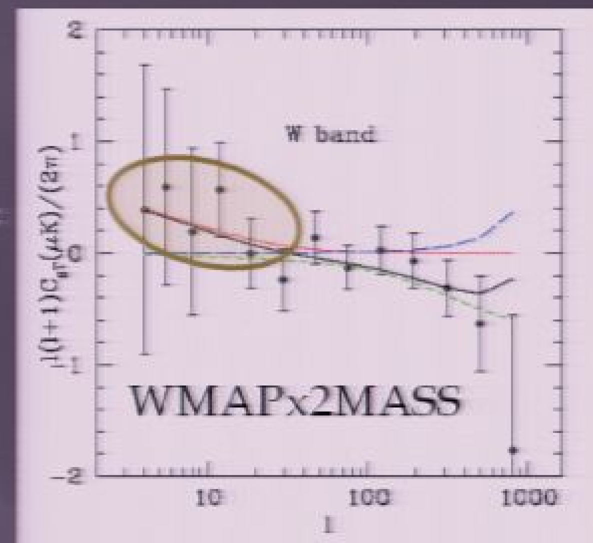

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- Independent Evidence for Dark Energy

Cosmic Convergence

- Science's No. 1 breakthrough of the year 2003

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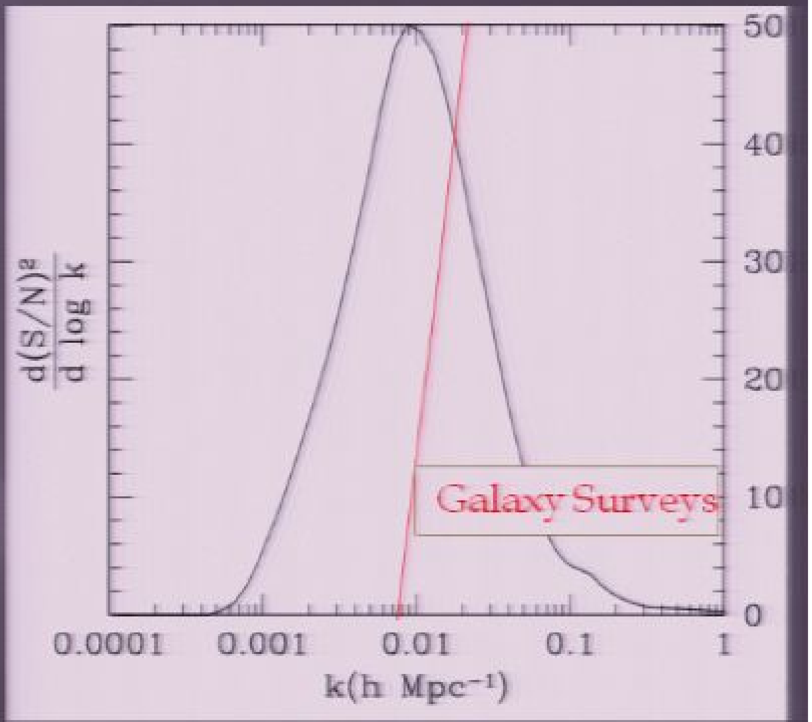

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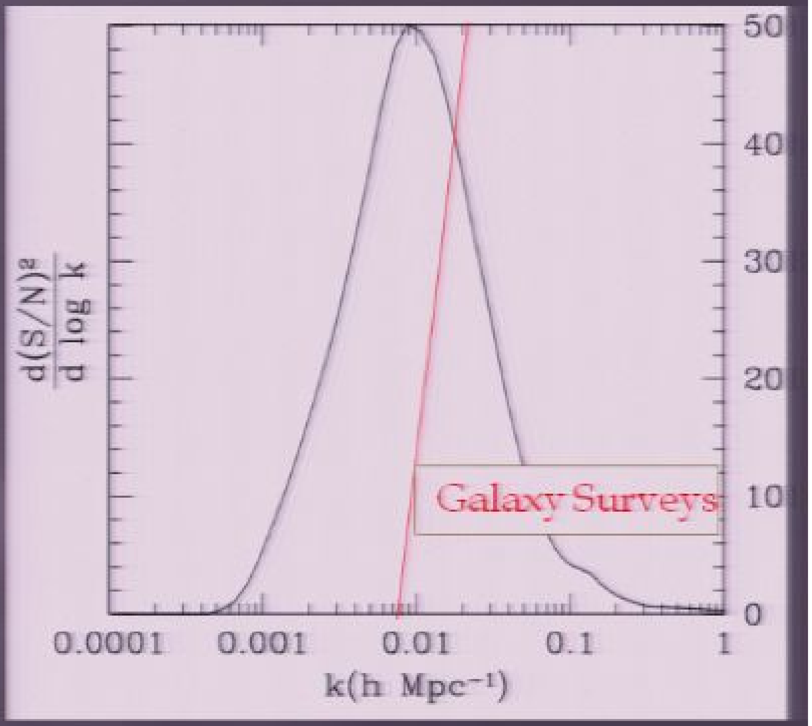

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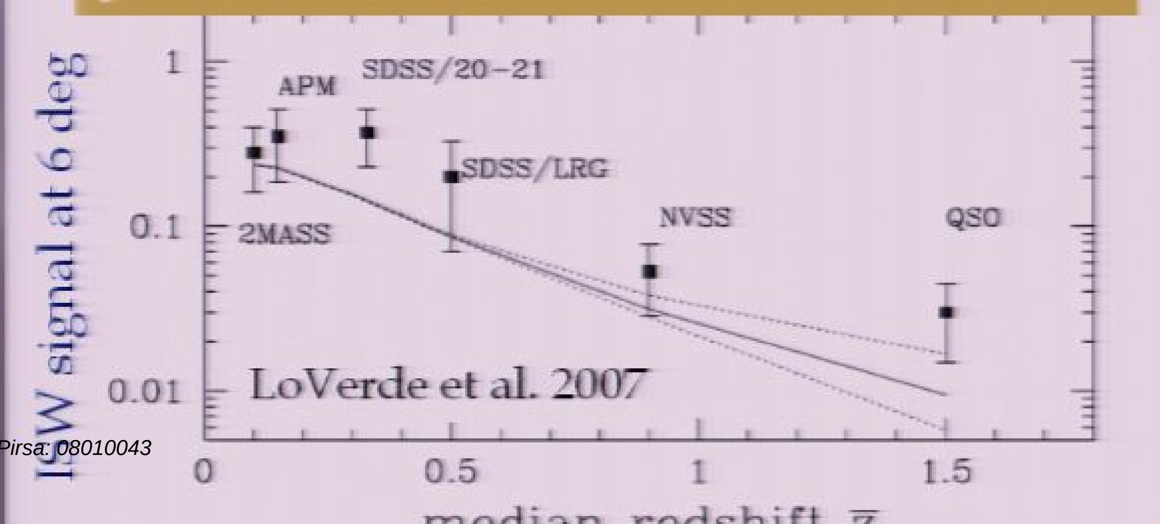

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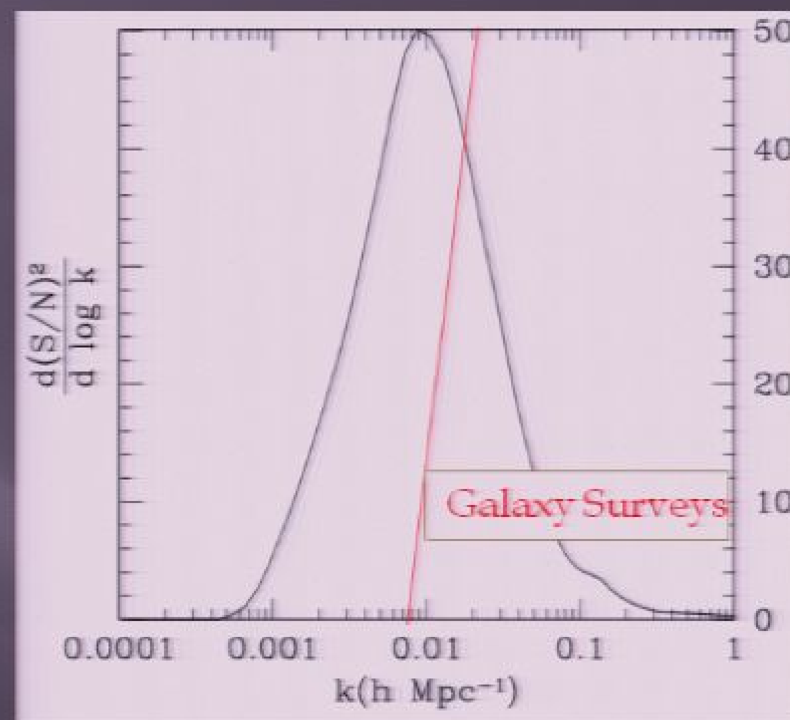

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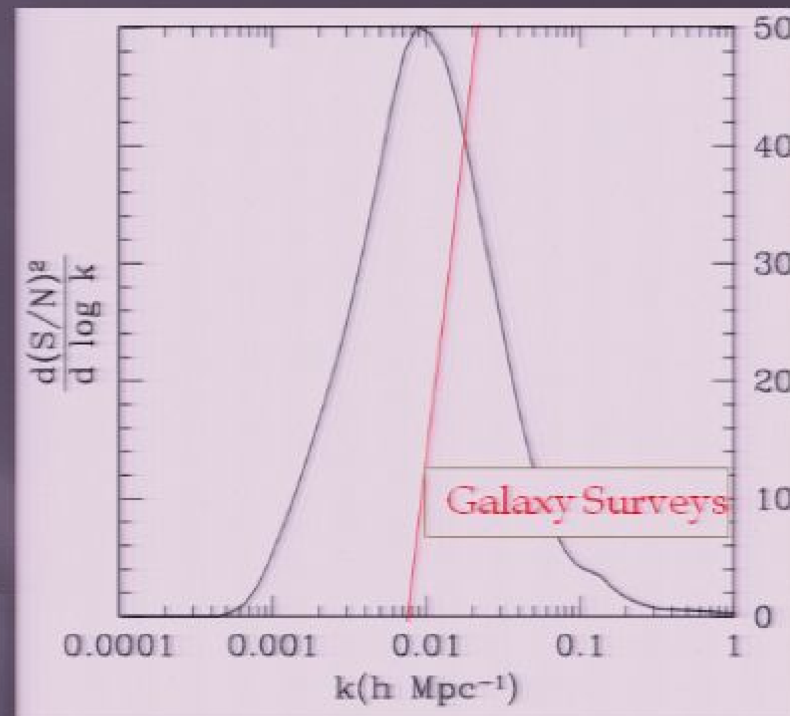

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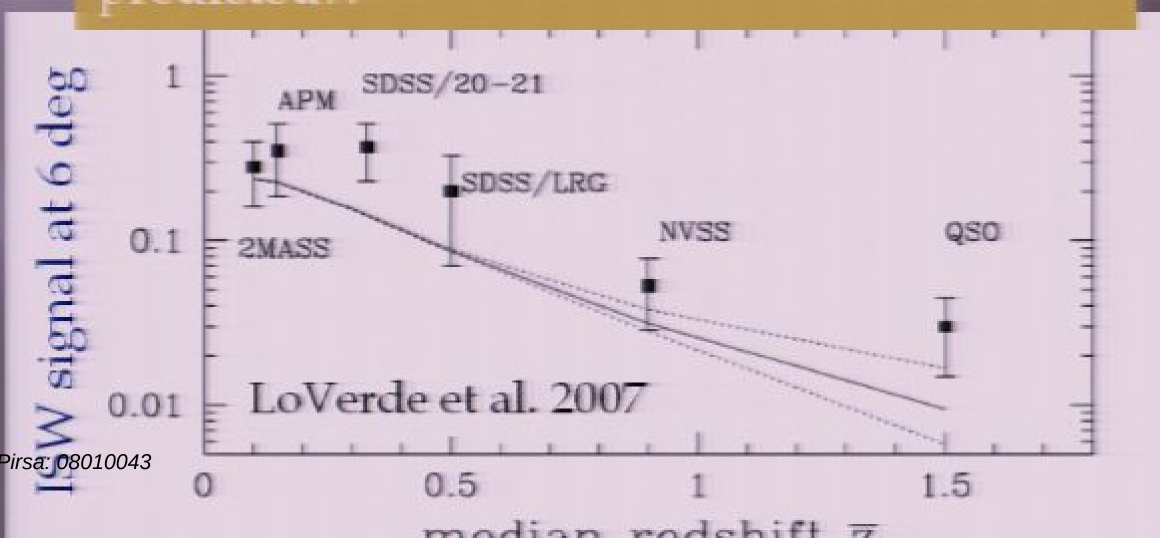

Gravity on Horizon scale

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  - Lorentz-violating vector field (Carroll & Lim 2004)
  - Cuscuton (Incompressible DE; Geshnizjani, Chung, & NA 2007)

Gravity on Horizon scale

- Friedmann Equation — Newtonian Gravity

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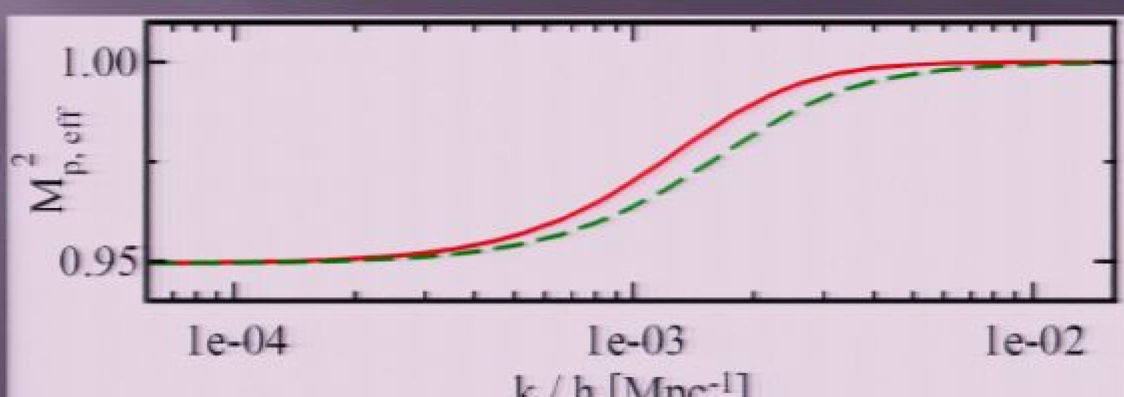

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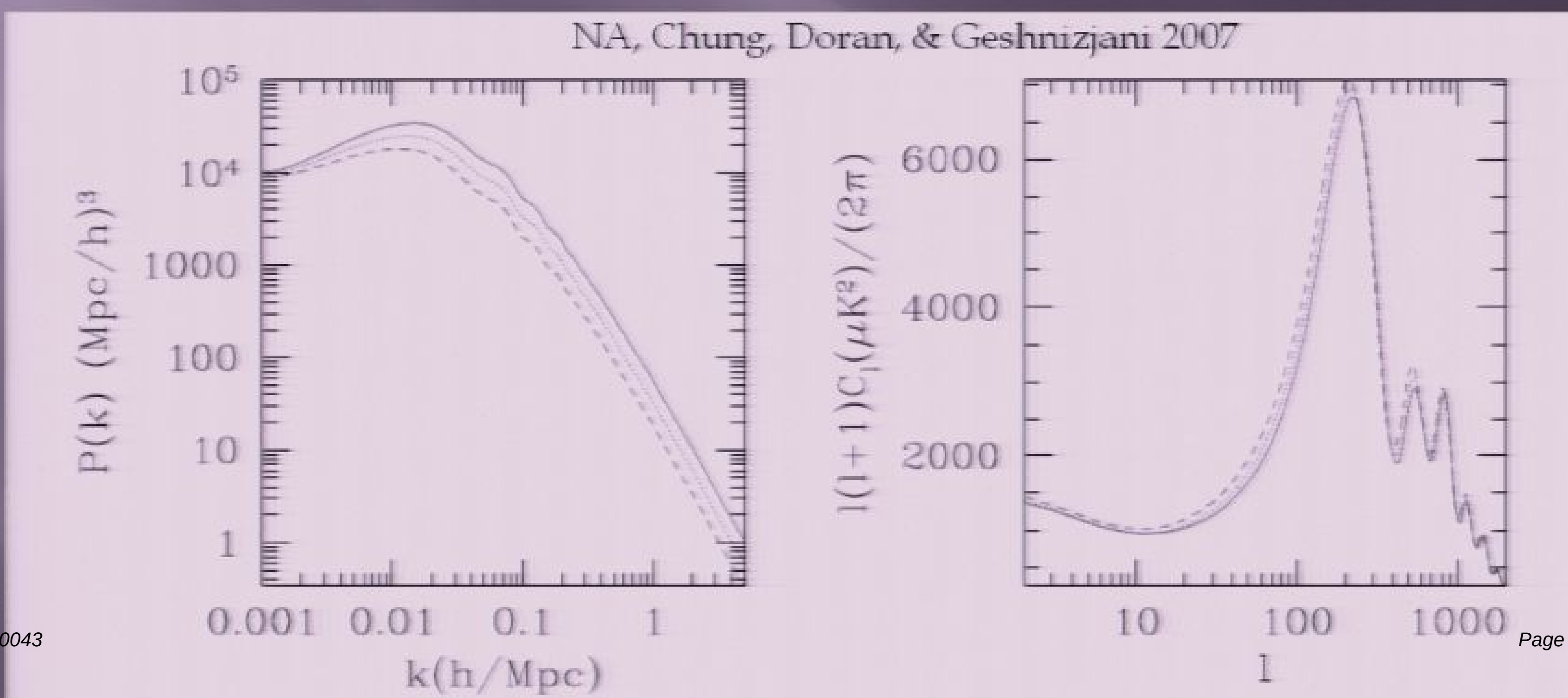

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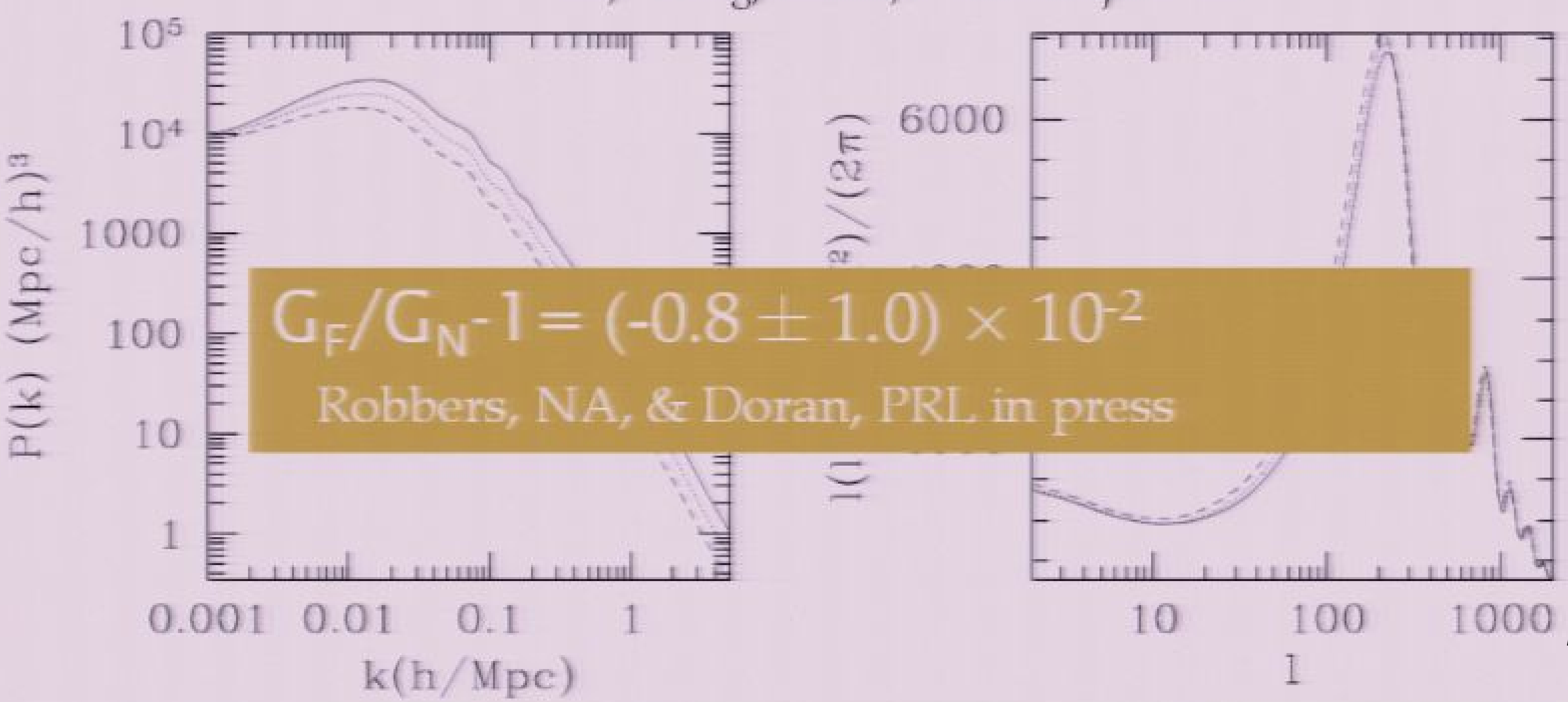
NA, Chung, Doran, & Geshnizjani 2007



$G_F/G_N - 1 = (-0.8 \pm 1.0) \times 10^{-2}$

Robbers, NA, & Doran, PRL in press

Statistics on Horizon scale

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→ Statistics on small scales (e.g. galaxies) could probe modes on the horizon scale

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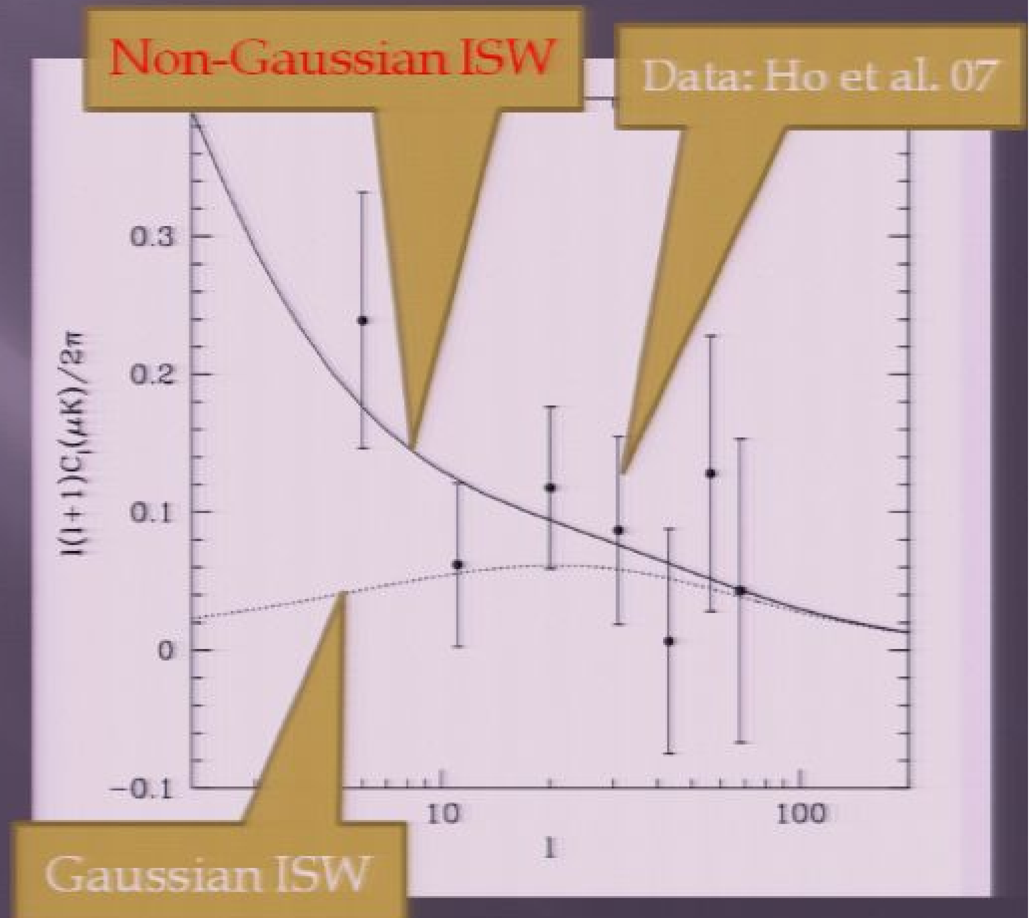

Cross-power spectrum NVSSxCMB
NA & Tolley, in prep.

Primordial non-Gaussianity, on the horizon

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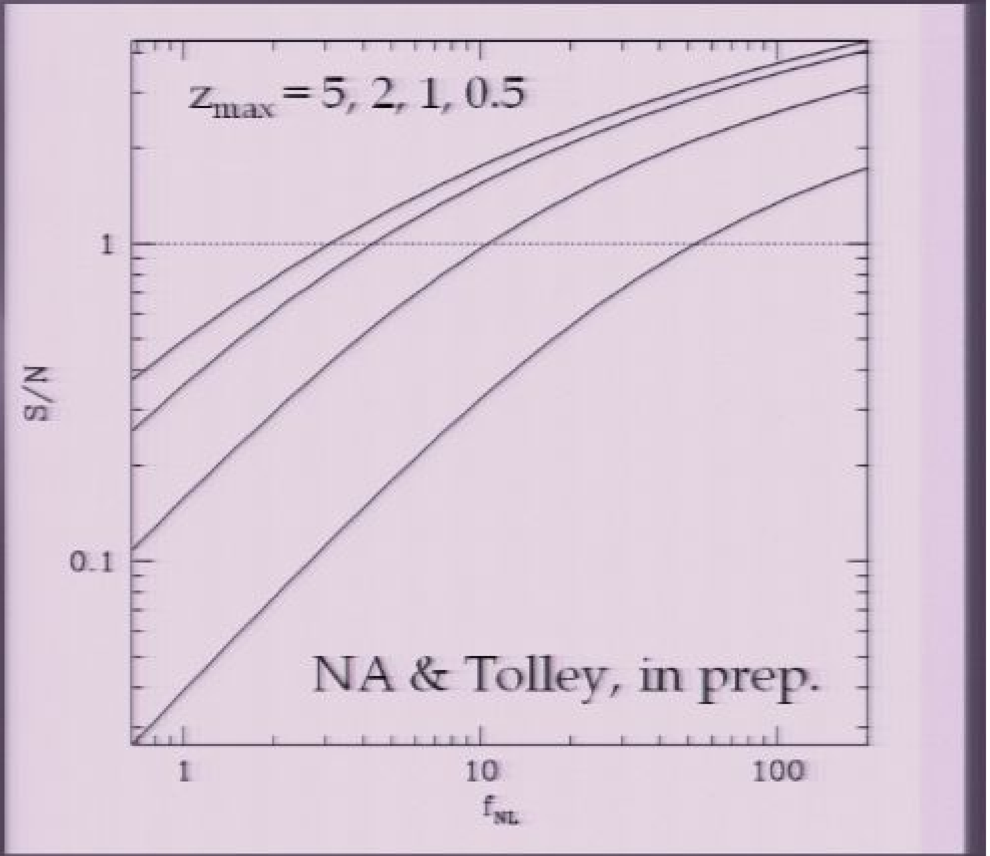

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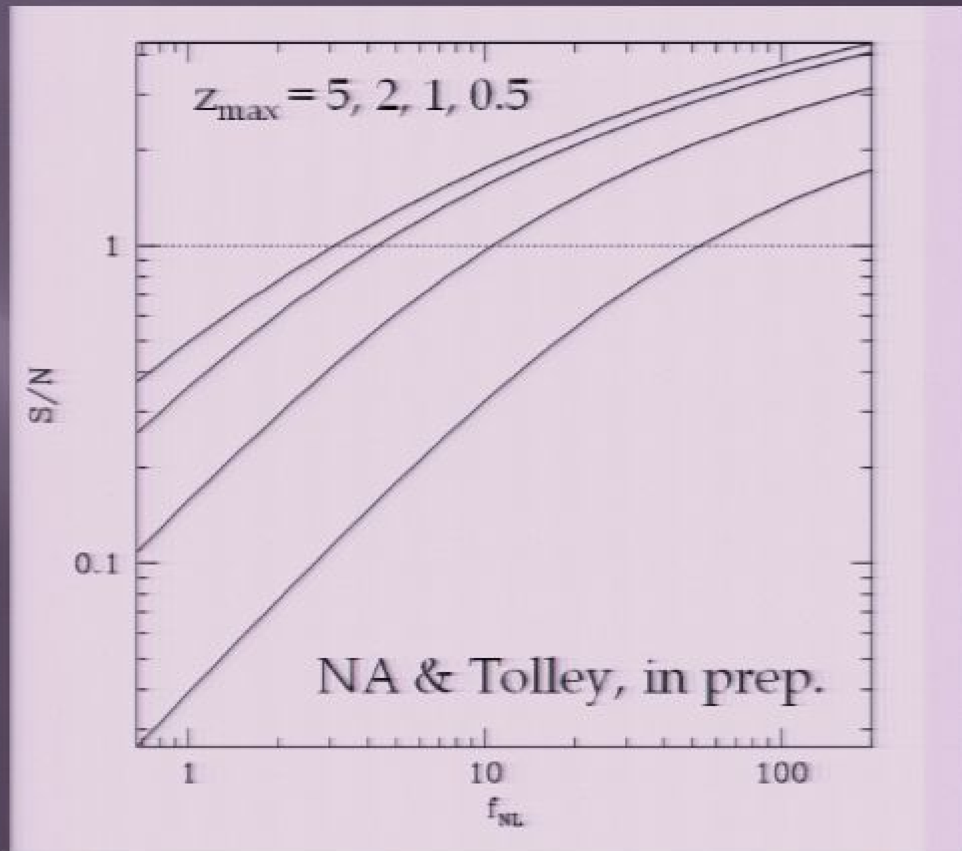
- Similar accuracy for upcoming large scale surveys (in lieu of systematics) ??



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- SZ cluster surveys: ACT, SPT, Planck, …
  - Large scale statistics of clusters → primordial non-gaussianity

Physics on the horizon …

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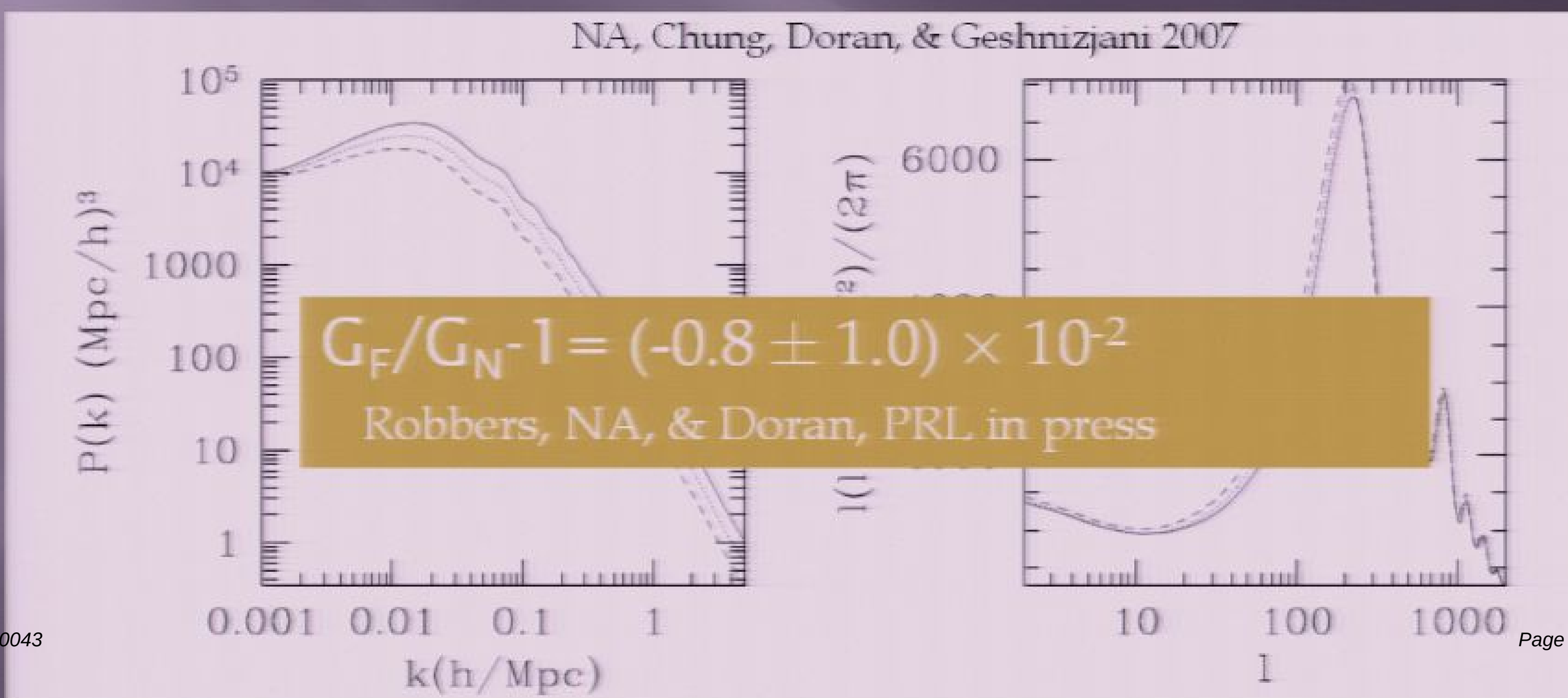

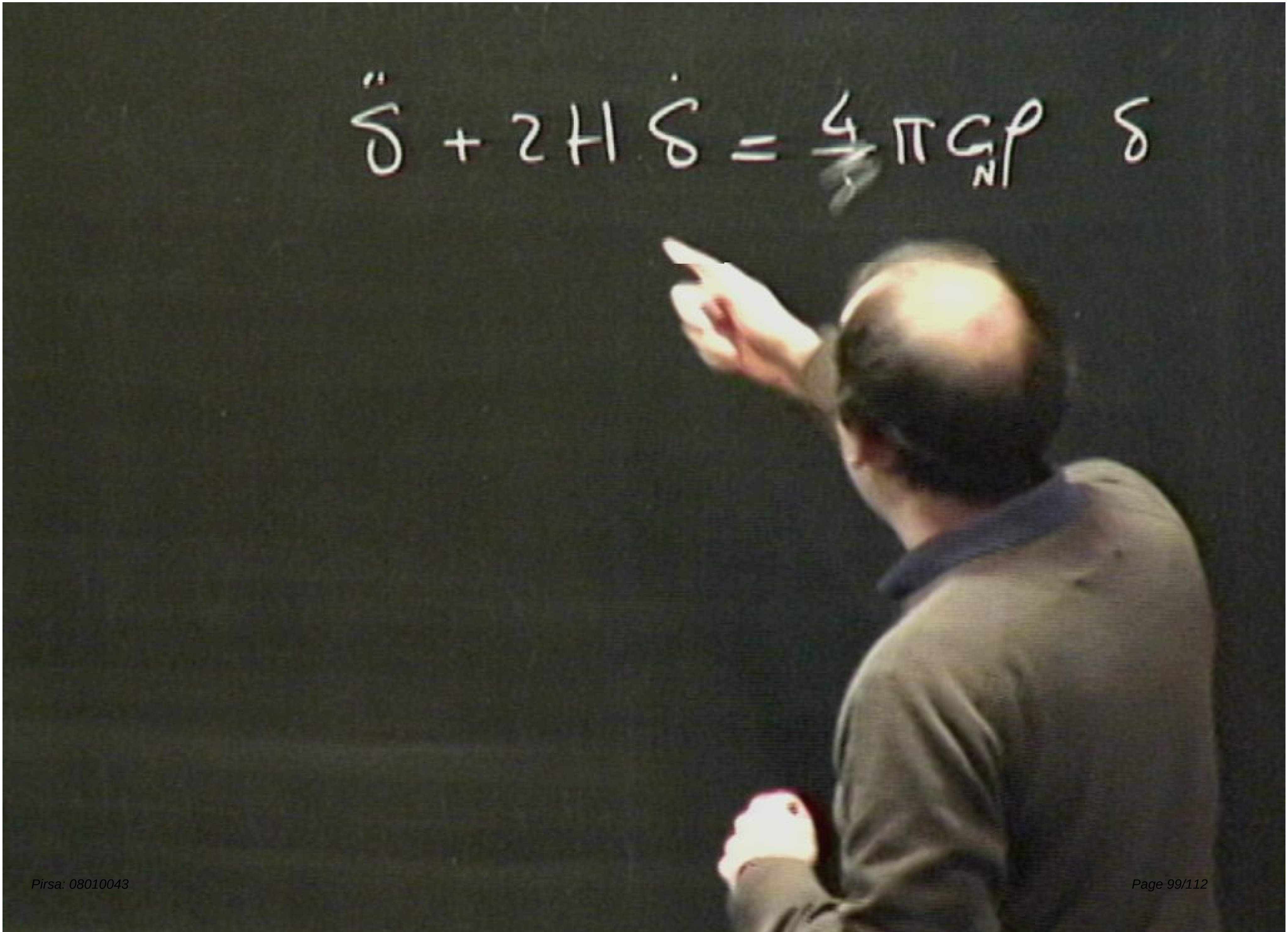
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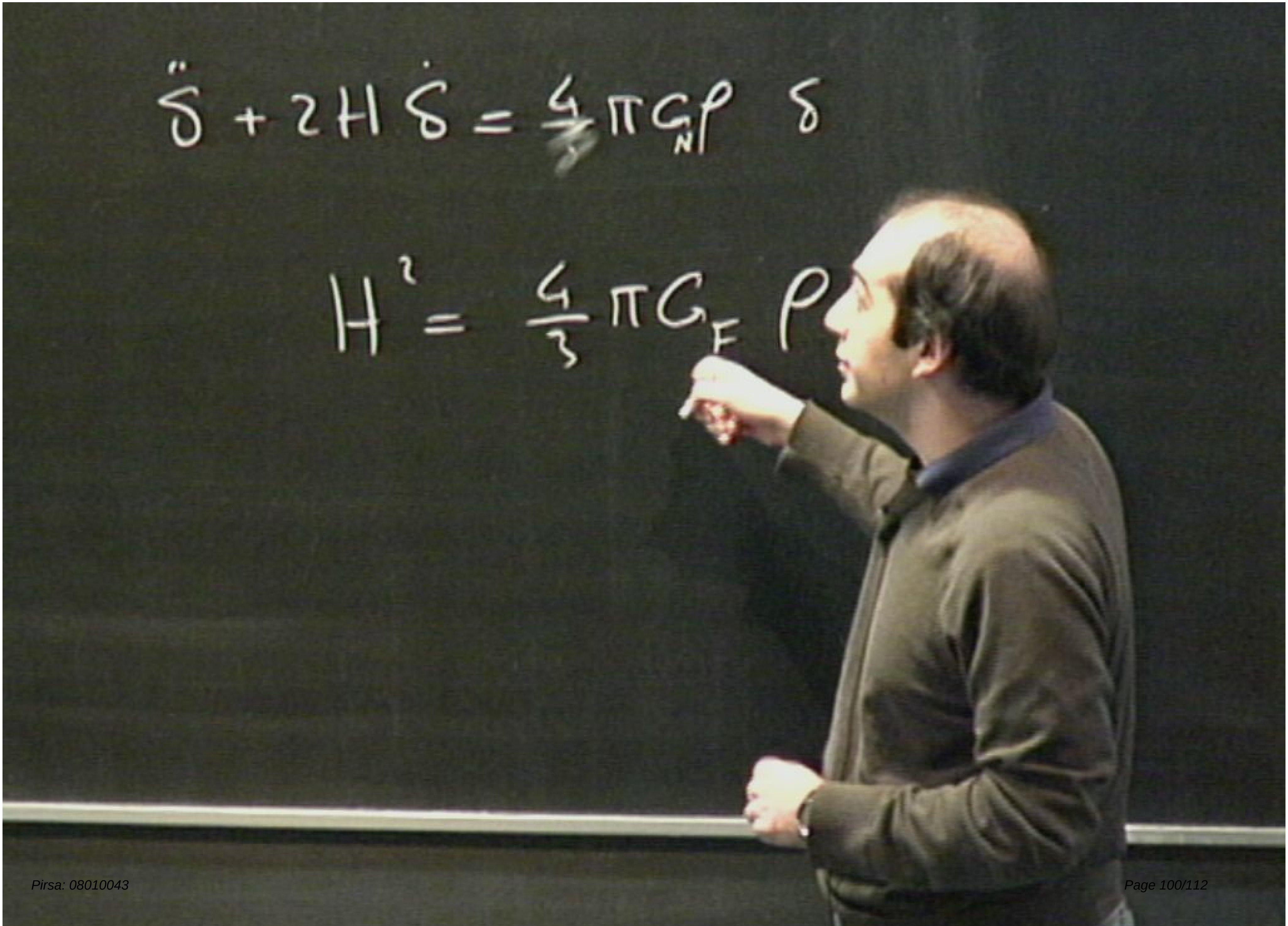
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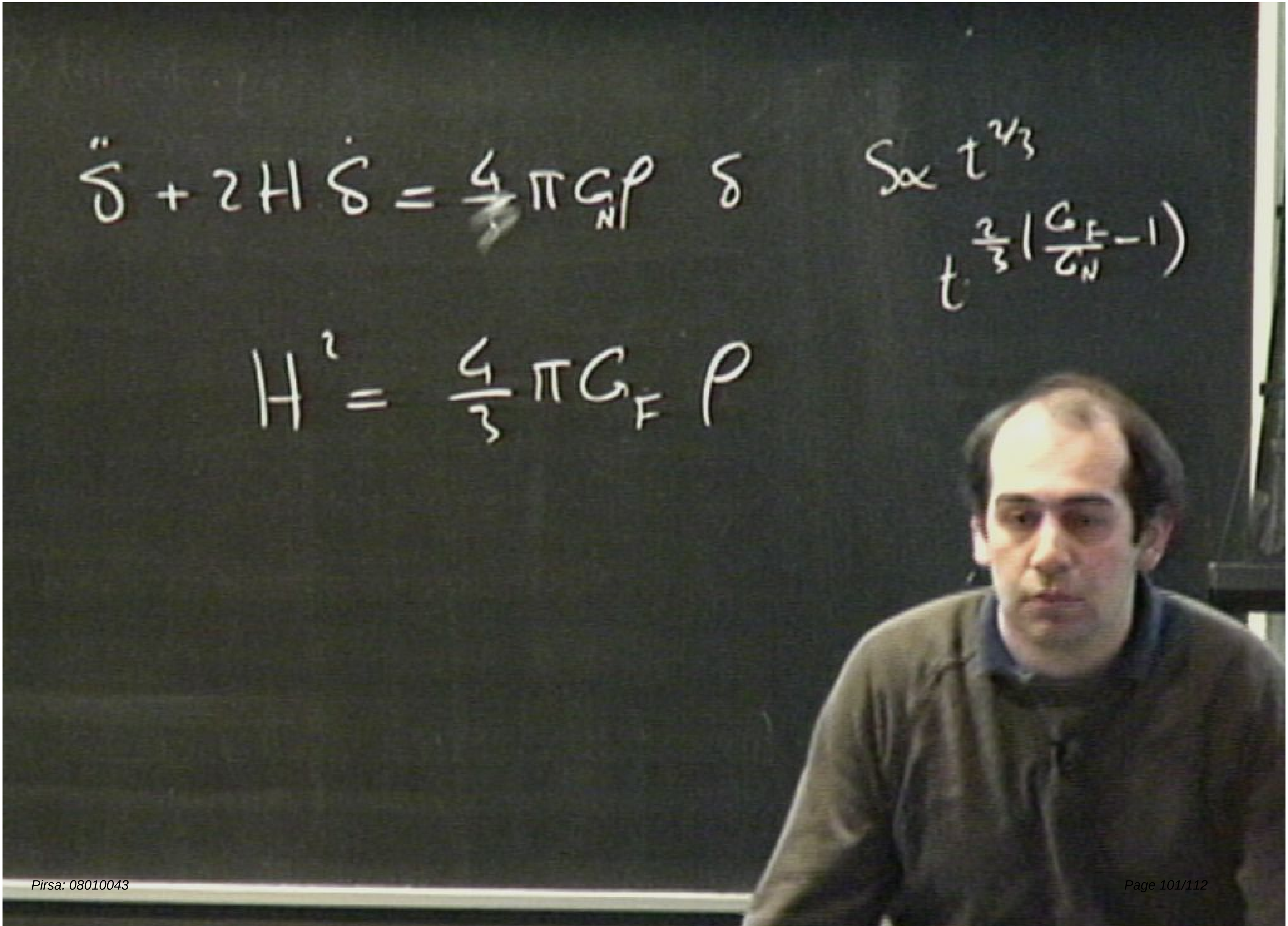
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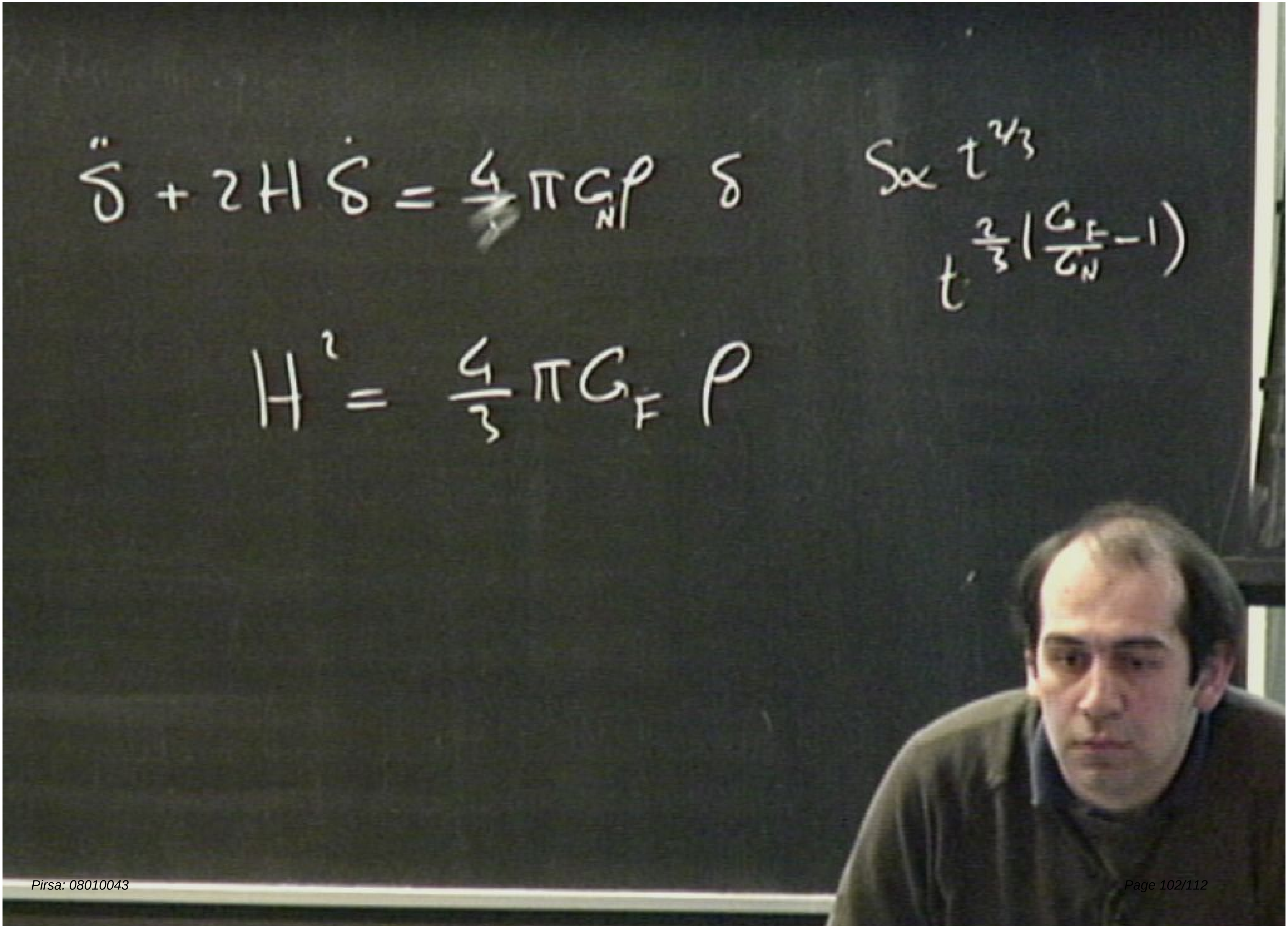
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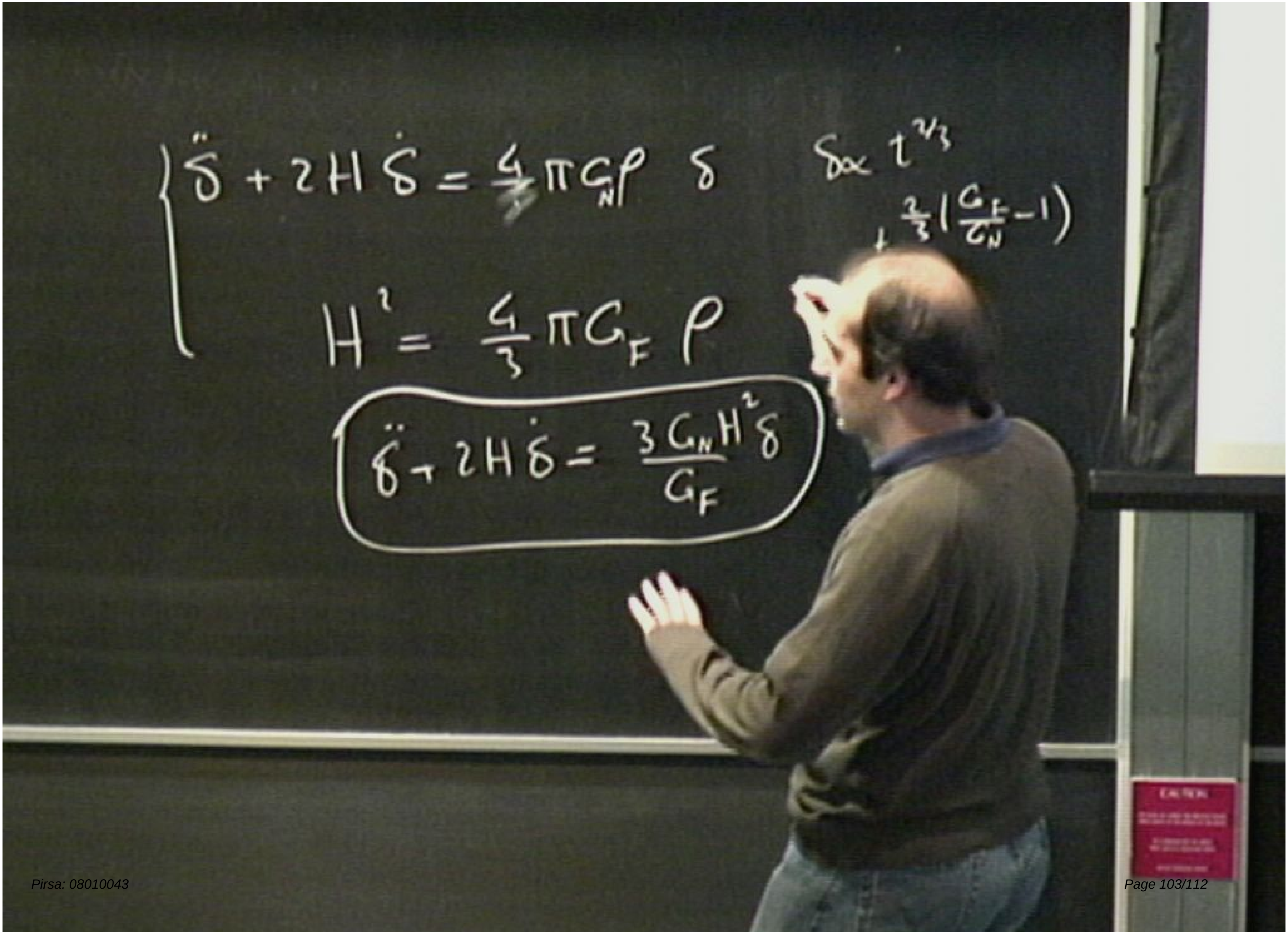
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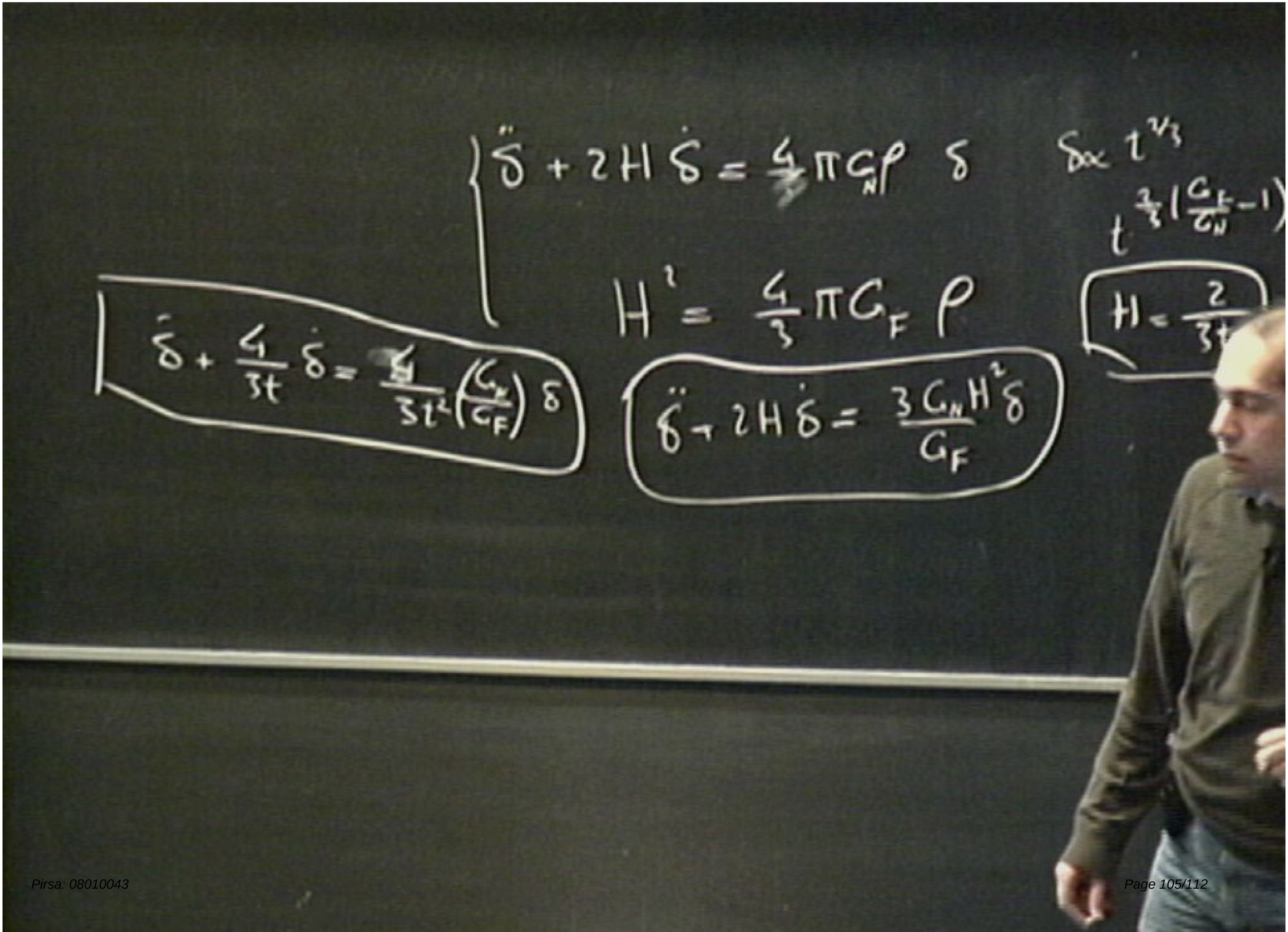

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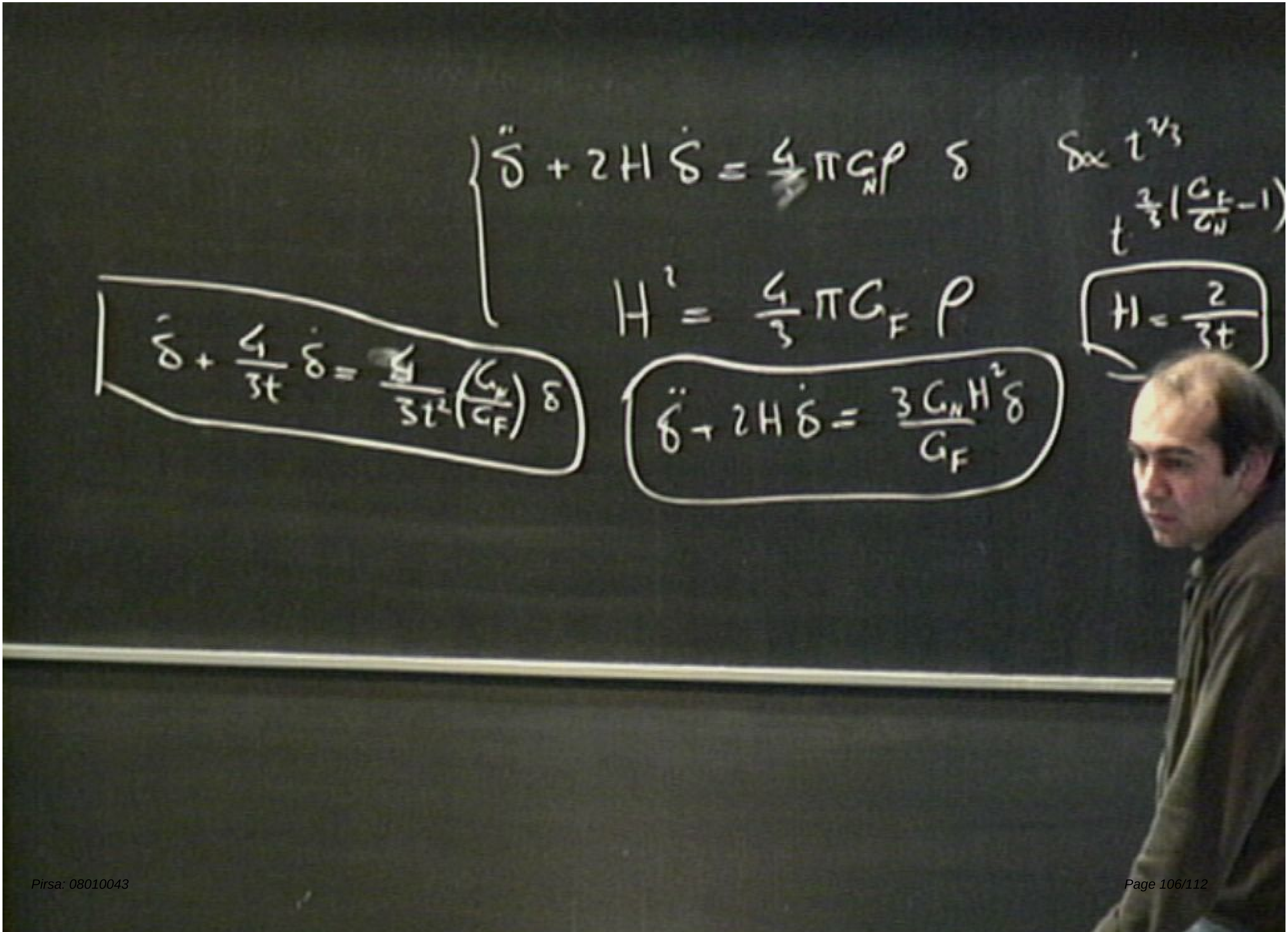
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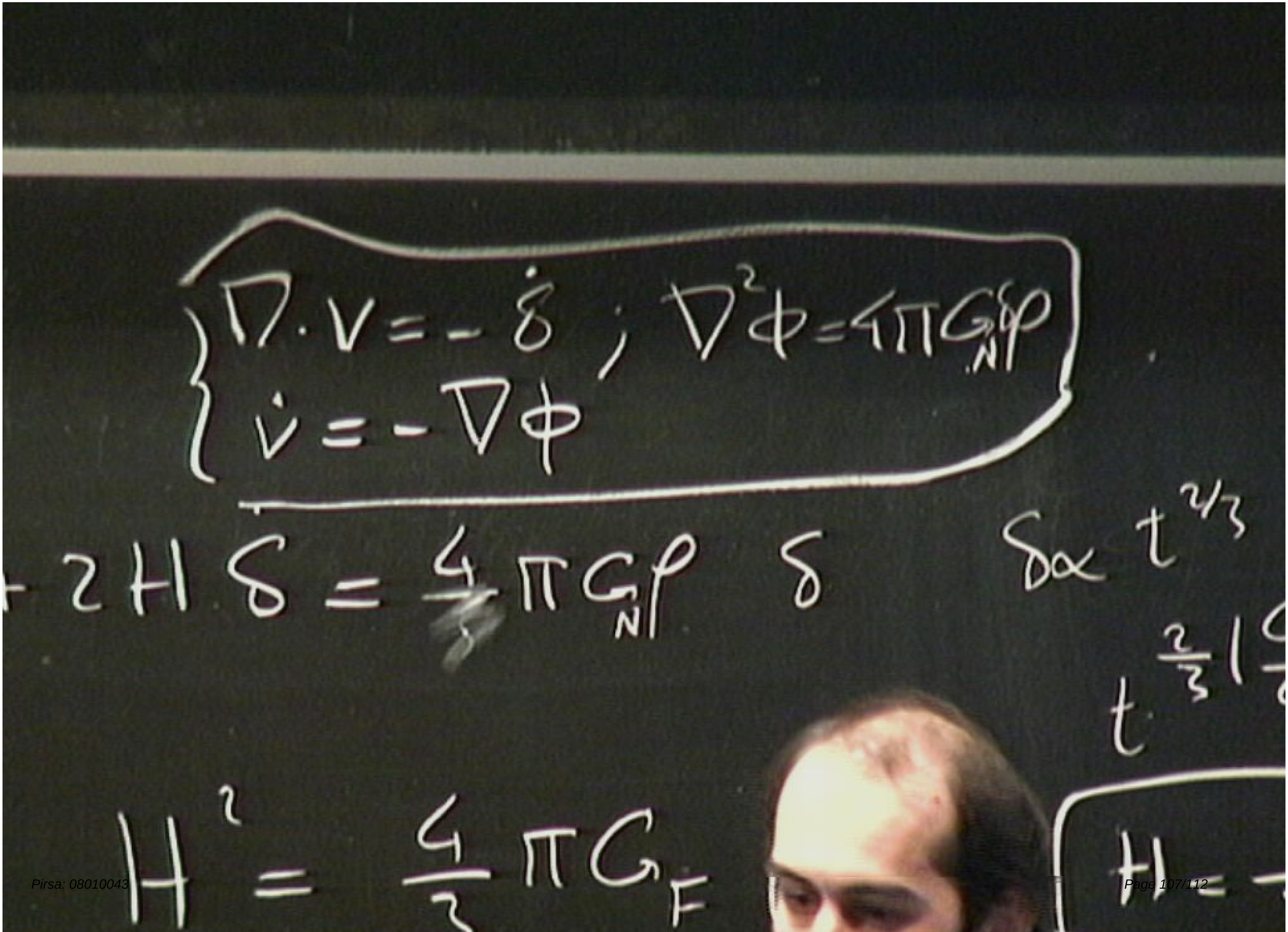
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δ ∝ t^{2/3}
H² = 4/3 π G_F

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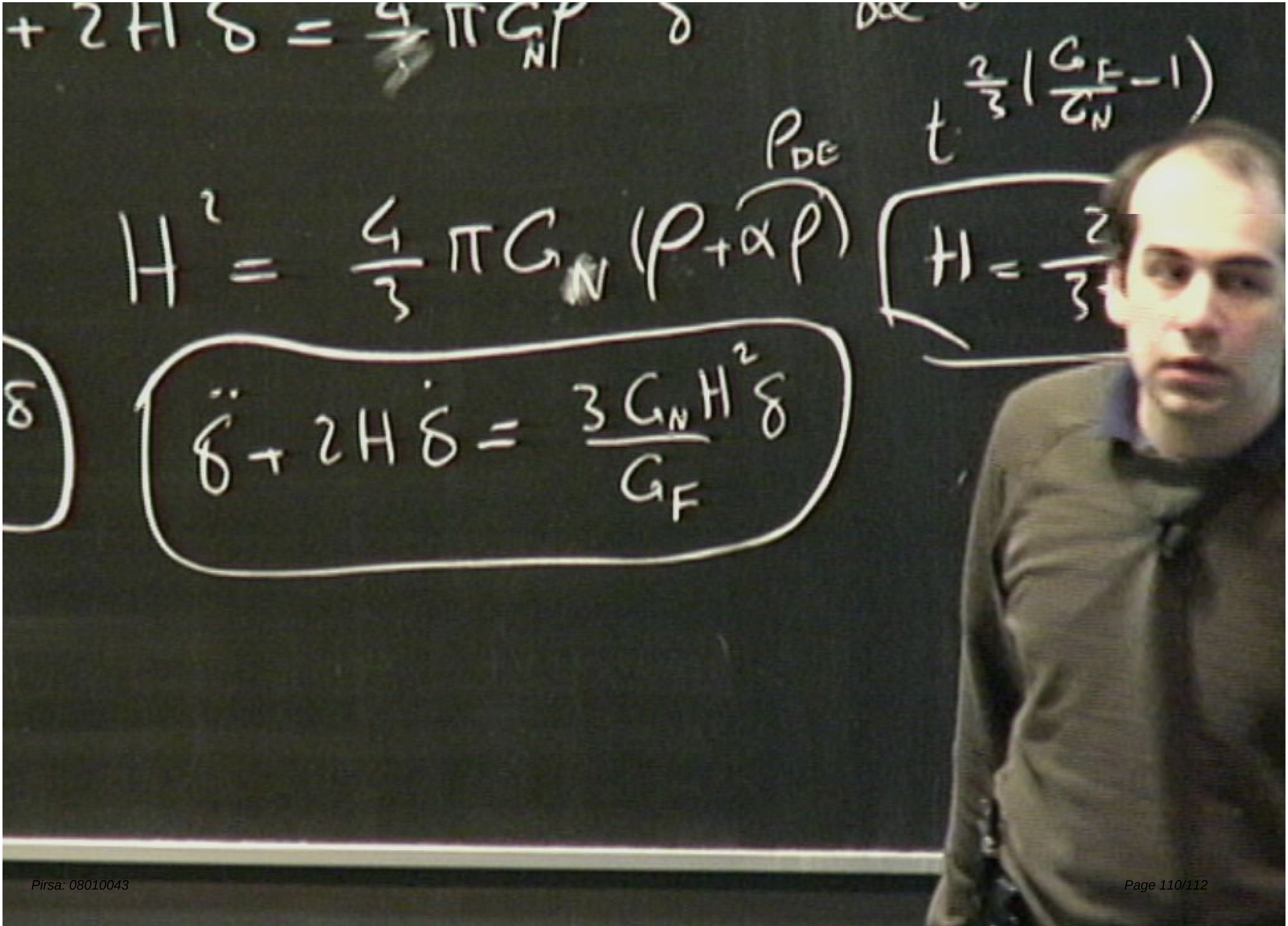
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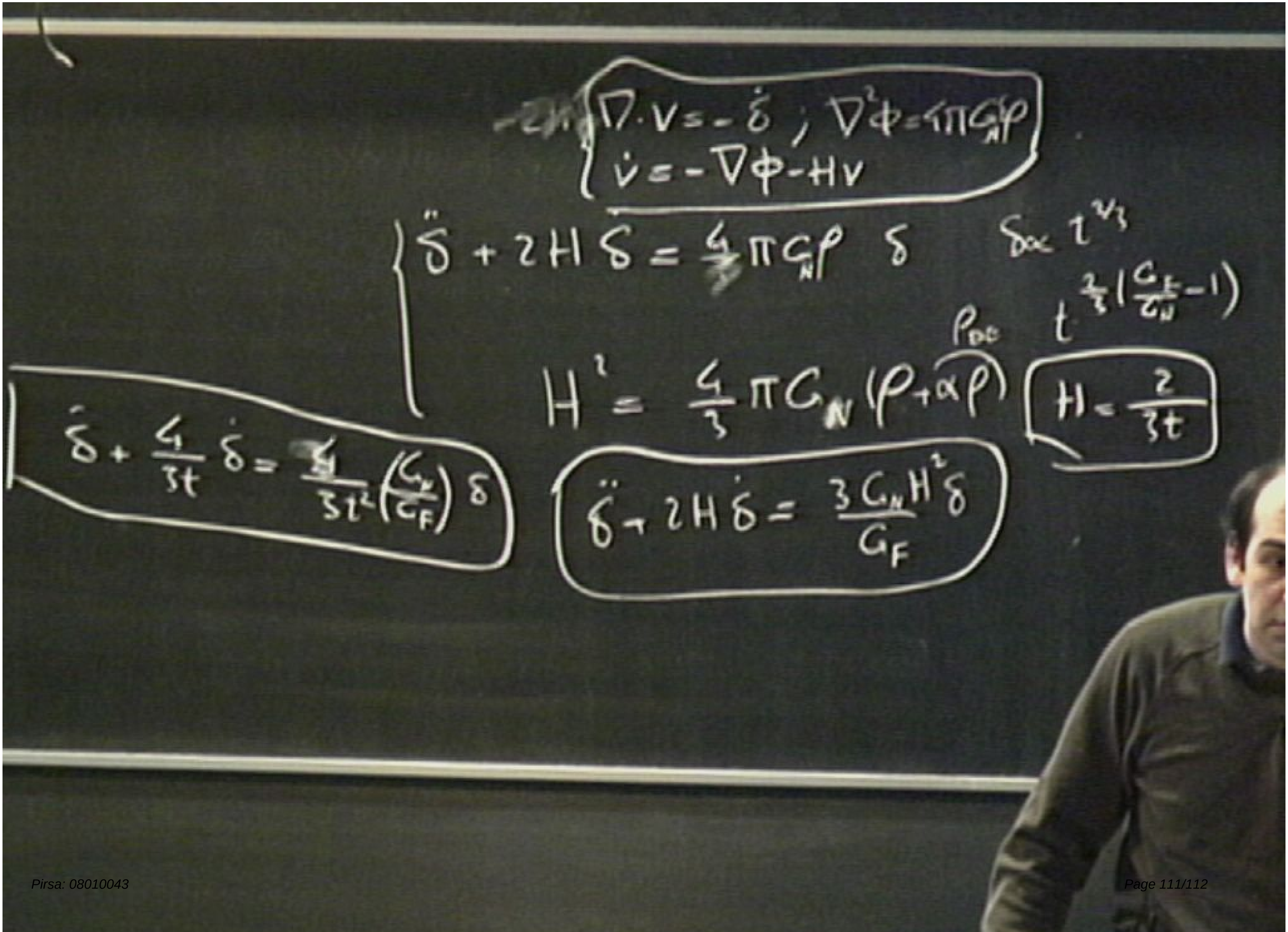
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Gravity on Horizon scale

- Friedmann Equation

$$\frac{\ddot{a}}{a} = -\frac{4\pi G_F}{3}\rho$$

Newtonian Gravity

$$F = \frac{G_N m_1 m_2}{r^2}$$

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